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ABSTRACT

After a discussion of experiential learning as an element in higher education and of the program evaluation process used in this study, six different but successful experiential learning programs in engineering are described and compared. From these comparisons some conclusions are drawn about important program elements. The six programs described are: the University of Cincinnati Professional Practice Program; the Harvey Mudd College Clinic program; the Kansas State University Mechanical Engineering Design Laboratory; the Worcester Polytechnic Institute PLAN program; the West Virginia University PRIDE (Professional Reasoning Integrated with Design Experience) program; and the University of Massachusetts ESIC (Engineering Services for Industry and Community) program. (MSE)

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American Society for Engineering Education

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Experiential Learning in Engineering Education

DEPARTMENT OF HEALTH
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Foreword

George Burnet
Ames, Iowa

Over the past year as the substance of the preceding report began to emerge from the several work session and site visits, it became apparent that timely and potentially significant new developments in engineering education in the United States were being revealed. Experiential learning has long been a part of engineering education in the form of special projects, instruction in design and cooperative programs but never with the variety and degree of innovation found today. Only the future can tell what the total impact of these developments will be, but fully evident is the debt the profession owes the Exxon Education Foundation for its foresight in initiating this study at this time.

During this decade there has been a growing interest in adding to the practice orientation of basic level engineering curricula. Responding to this interest the Engineers' Council for Professional Development revised accreditation criteria in 1974 to strengthen requirements for the practice or design component ''in recognition of the need to orient the engineering study toward the solution of important technological problems of society'' (page 69, 42nd Annual Report). The criteria define engineering design as the process of devising a system, component or process to meet desired needs, and suggest that sociological, economic, aesthetic, legal and ethical considerations be included.

More recently, support for the ECPD position is to be found in views expressed at the 1975 World Congress on Educating Engineers for World Development sponsored by the American Society for Engineering Education at Estes Park, Colorado. Speakers strongly emphasized the essential role of experiential learning in the future of engineering education not only in the United States but also in the developing countries. It was agreed that this element in engineering curricula is necessary to provide a true learning experience for gaining the skills needed to deal with the complex, interdisciplinary problems of the developing societies and that it should not be a haphazard period of work or poorly supervised.

The question then is, how can emphasis on practice through some form of experiential learning be made an integral part of engineering education at the various levels required today, while still maintaining the necessary quality, breadth, and depth of training? Oliver Wendell Holmes, in his essay "The Autocrat at the Breakfast Table," in 1858, defined a philopsophy appropriate to the dynamic nature of engineering education as we find it today:

> "I find the great thing in the world is not so much where we stand, as in what direction we are moving...We must sail sometimes with the wind and sometimes against it but we must sail, and not drift, or lay at anchor."

This study may well help set the rudder for what appears to be a new direction in engineering education, that is, a reemphasis on engineering practice, design, and professionalism. It provides an objective and comprehensive coverage of significant developments in experiential learning in engineering education that deserves attention.

Preface

There is an increasing emphasis in engineering education on engineering practice and internship before graduation. The inclusion of authentic involvement project activities in the degree programs is common among new and innovative curricula, and is receiving enthusiastic response from students, faculty, and cooperating industries. However, there is a need to compare the various programs of internship and clinical-type experience in engineering education to determine the procedures and program strategies that are successful. There is also a need to know what changes occur in the learner because of the authentic involvement activities, to know what learning objectives are or can be met by these activities, and to make some kind of assessment as to the weight these activities should have in the degree program.

This report is the result of a study to evaluate experiential learning in engineering education. The intent of this study was to determine the learning outcomes and learning potential of experiential project activities in several different models currently underway in the United States. The objective was to evaluate the effectiveness of each of the programs in achieving the various outcomes that were expected by the developers of the programs. No attempt in any way was made to rank, rate, or select out those programs that should become the learning model for others to adopt. Instead, the investigation was designed to obtain the most comprehensive, comparative profiles of the various program models that would be possible within the scope of the study.

The study was conducted by Dr. Lee Harrisberger with the assistance of Richard Heydinger, John Seeley, and Margaret Talburtt, members of Formative Evaluation Research Associatives (FERA) at Ann Arbor, Michigan. FERA is an independent partnership of PhD candidates in the Center for the Study of Higher Education at the University of Michigan formed to conduct action-oriented formative evaluation of various innovative educational projects.

It was proposed to concentrate the study on six different project-oriented experiential learning models. Each was uniquely different in concept and implementation. The proportion of the degree program which was committed to the experiential learning model ranged all the way from zero credit hours to total commitment. The newest model has been in operation only a year, and the oldest model has been in operation over seventy-five years. The programs vary in student involvement from a very small selected subset of students in a single department to a total degree program commitment for all students in the institution.

The Six models studied were:

a. The Worcester Polytechnic Institute PLAN program involving a real life project experience with off-campus clients, including both technical projects (MQP) and socio-economic interdisciplinary projects (IQP);

b. The University of Massachusetts ESIC program involving a directed engineering education program in the Department of Mechanical Engineering and an authentic involvement type of project activity with industrial clients;

c. The Harvey Mudd College Clinic program, an authentic involvement type of activity involving campus-based funded projects from industry and required of all engineering students;

d. The University of Cincinnati Professional Practice program, one of the oldest cooperative engineering education programs in the United States;

e. The West Virginia University PRIDE program in the Department of Chemical Engineering, a case/simulation type of project activity centered on faculty created projects;

f. The Kansas State University Mechanical Engineering Design Laboratory required a senior laboratory in which students solve problems obtained from industry.

Each site visit involved a highly structured, on-site interview procedure conducted by Dr. Harrisberger and two members of the FERA team. The objective was to obtain opinions, attitudes, and experiences from the faculty, administrators, students, alumni, and client supervisors. The responses from these individual hour-long interviews were recorded on a lengthy interview form. Each was given a standardized response code and computer processed to provide a large data bank of comparative information from which this report was derived.

Each of us involved in the study is particularly appreciative of the cooperation and hospitality we received on each of the site visits. During the course of study we interviewed 60 faculty and administrators, 76 students and alumni, and 22 off-campus client supervisors. This necessitated a very well-organized and tightly scheduled two-day site visit at each institution. We extend our sincere appreciation and thanks to the leaders and coordinators of these programs: John Dixon at the University of Massachusetts; Joseph Mielinski at Worcester Polytechnic Institute; Thomas Woodson at Harvey Mudd College; William Wilson at the University of Cincinnati; John Sears at West Virginia University; and John Lindholm at Kansas State University. Each has a leadership role in the development and implementation of these unusual experiential models, and each did an outstanding job in providing us with an extremely efficient, well-organized, and hospitable site visit. We also extend our thanks and appreciation to George Burnet of Iowa State University who served as project consultant. His probing questions were a valuable contribution to our planning conferences.

We hope that this study has recorded the valuable experiences that have been obtained in the operation of these established experiential learning models. If this information will encourage more widespread study of the role of experiential learning in the education of the engineer, our time has been well spent, the Exxon Foundation has been well served, and engineering education and the engineering student will benefit.

This study was sponsored by the Exxon Education Foundation through a grant to the University of Texas of the Permian Basin at Odessa and directed by Dr. Lee Harrisberger, who was Dean of Science and Engineering at the time.

Experiential learning

Experiential learning has always been and perhaps always will be an important component in the educational process. In the 25th Century B. C. Confucius was lecturing his own faculty colleagues that they should..."show the students the way but never take them to the place." The early Greek universities are known for their master-apprentice approach to education. Throughout the centuries all the crafts, trades, and professions have used the apprentice-internship method for achieving competence.

Learning by doing is fundamental to the educational process. "Experience is the best teacher" and "practice makes perfect" have always been regarded as fundamental axioms. Apprenticeship, internship, and practicum have always been a component of skill-oriented study programs. The laboratory has always been regarded as a necessary component of the educational process. The longevity of the experiential learning process throughout the history of higher education testifies to its importance to the learning process. Even so, the opportunities in experiential learning activity have never been fully exploited. Many degree programs, where the experiential component should be regarded as a necessity to the learning process, provide little opportunity for the student to learn by doing.

The Motivating Forces

Anyway you say it, engineering is man's effort to control and utilize nature for his own benefit. This process involves the adaption of scientific discoveries, the creation of useful devices, the process of inventing solutions, the solving of problems, the conversions of the forces of nature, and the conversion of energy resources. All are "doing" activities and all these activities are best learned by experiencing. In the first half of this century, engineering education was strongly oriented toward the technology of engineering. The curricula was heavily oriented to techniques or manufacture, operation, testing, and maintenance. There was a strong motivation to have all engineering students acquire the mechanical skills associated with manufacture and operations. The students were required to enroll in many hours of "shop" to learn the techniques of welding, casting, pattern making, machine shop, machining, etc. The advanced laboratories were devoted to learning how to operate and test complex machinery and instruments. A large percentage of the engineering student's contact time was spent in laboratories. Up to thirty contact hours per week were involved in this type of experiential activity.

In the post-Sputnik era of the second half of this century, the motivating force was research and development. Engineering was perceived as being responsible for the creation and application of more sophisticated devices utilizing the newest scientific discoveries. Computer technology provided the engineer with a more sophisticated analytical tool, and synthesis, analysis, and design became the "need-to-know" in engineering. In 1967, the interim Goals Report of the American Society for Engineering Education stated:

> "Regardless of the academic route, the central characteristics of engineering is the creative synthesis of new systems and components. New learning experiences in this direction are much needed and should provide a real challenge in engineering education...Group design projects, use of the case methods, and other possibilities have been considered and are being tried in a few places but more experimentation is needed...There is both need and opportunities for a limited amount of learning experience other than that obtained in formal courses, and this can be given different emphasis for different students. This emphasis could indeed be oriented toward creative design experience...The majority of the responders felt that design is the heart of engineering and its importance will increase in the future, thus the creative teaching of design offers opportunites for experimentation and improved pedagogy."

The recognition of creative synthesis and design as a central characteristic of engineering put a decided emphasis on the business of creating ideas to adapt scientific discoveries to the development of a useful product. It was a recognition of a need for skills in the creative act of selecting, combining, converting, constraining, modifying, manipulating, and shaping ideas, scientific facts, and physical laws into a useful product or process.

The Engineers' Council for Professional Development (ECPD) states in its manual of objectives and procedures for accrediting programs in engineering in the United States that:

> "...the curricula content of the programs to include...one-half year of engineering design... The requirements for course work in engineering design specified for basic and advanced level programs have been established in recognition for the need to orient the engineering student toward the solution of important technological problems of society. In this context engineering design is the process of devising a system, component, or process to meet desired needs. It is a decision-making process (often iterative) in which the basic sciences, mathematics, and engineering sciences are applied to convert resources optimumly to meet a stated objective. Among the fundamental elements of the design process are the establishment of objectives and criteria, synthesis, analysis, construction, testing and evaluation. Central to the process are the essential and complementary roles of synthesis and analysis. This definition is intended to be interpreted in its broadest sense. In particular, the words system, component, or process and convert resources optimumly operate to indicate that sociological, economic, aesthetic, legal, ethical, etc. considerations can be included."

This emphasis on the inclusion of a component of design experience in the engineering curriculum by the ECPD accrediting process necessitates a learning activity that must have a significant experiential component.

Although the recommendations of the Goals study and the criteria of the accredidation process place a great emphasis on the need for an experiential component oriented towards design in the present on-going engineering education process, there is a need to look to the requirements of the future. Alvin Toffler in his book, **Future Shock**, forecasts the demands the future will make on the experiential component of the educational process:

> "For education the lesson is clear; its prime objective must be to increase the individual's cope-ability, the speed and economy with which he can adapt to continual change... He must, to put it technically, learn to make repeated, probabilistic, increasingly long range assumptions about the future... Frederick J. McDonald has proposed a 'noble education that takes the student out of the classroom...to participate in significant community activity ... If learning is to be stretched over a lifetime, there is reduced justification for forcing kids to attend school full-time... Experiential programming methods, drawn from recreation, entertainment, and industry... will supplant the familiar, frequently brain-draining lecture... The range of subject matter should be broad enough so that apart from dealing with the known elements of this enterprise some provision would be made for

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> dealing with the unknown, the unexpected, the possible... Tomorrow's schools must therefore teach not merely data but ways to manipulate it. Students must learn how to discard old ideas... They must learn how to learn... Tomorrow's illiterate will not be the man who can't read; he will be the man who has not learned how to learn."

It is quite evident that the future is going to demand more of experiential learning in the educational process than it has in the past. The emphasis in the direction of design in engineering education is going to put a more sophisticated demand on the experiential learning activity than was formerly met by the skill-oriented laboratories of the past.

The Fundamental Strategy

Although experiential learning is accomplished in various ways for a variety of motives and with varied outcomes, there is a basic strategy involved. Many of the procedures used in the experiential learning activities are derived from the intuition that develops from personal experience. A large portion of an individual's learning is obtained through experience. In fact, all of the learning that is obtained before the age of six is experientially based. Much of the learning that goes on after the conclusion of formal education is also experientially based. It is not, therefore, hazardous to undertake the development of an experientially based learning program based on the intuitive insights of personal experience without any prior knowledge of the learning process that is involved. As a matter of fact, only in recent years has any formalized strategy for the development of any program in higher education been based on the fundamental concept derived from educational research. Most of us who have been in higher education for a number of years operate as rank amateurs when it comes to having a background in educational techniques.

In the past decade a number of new innovations in educational procedure in higher education have come on board which have been derived from sound educational fundamentals. This has sparked a number of publications on pedagogical fundamentals written for the "layman" followed by workshops to teach the faculty how to implement these basic concepts to develop new and effective learning activities.

Recently a number of taxonomies (classifications of educational objectives) have emerged to document the learning sequence followed by students in the learning process. Probably the most familiar and well-known is Bloom's taxonomy for the cognitive domain. It has been followed by taxonomies for the affective domain, the psychomotor domain, and just recently, the experiential domain. Each of these taxonomies trace the levels of increasing sophistication that learners pass through as they proceed from the beginning of their awareness to the limit of behavioral change.

Although the authors of the taxonomies have filled in a rather elaborate sequence of steps and branches, the trajectory of the learner can be summarized in five or six major steps or levels. Table 1.1 shows a rather cryptic summary of the levels for each of the four basic taxonomies. There are a number of ways that some understandings can be derived from the taxonomy table. The objective here, however, is merely to provide a rather simplistic "layman's" interpretation. At least it may give some credibility to the logic that is involved in the development of an effective learning activity.

The first three levels in the taxonomy table could be interpreted as child-level activities of learning in each of the domains. That is, these levels have a specific training orientation towards the obtaining of skills, repeatable and usable skills. These three levels involve most manipulative, habit forming, non-judgmental activities. Some of the studies of pedigogical activities claim that most of the learning activities employed in courses of higher education rarely exceed Level III and are primarily devoted to the skill acquisition level. This is especially true in courses at the freshman, sophomore, and junior years.

Levels IV, V, and VI in the taxonomy table might be interpreted as adult learning activities. These involve the complex mental skills that are required to synthesize, combine, transfer and adapt knowledge from one situation to another with skill and sophistication. To put it another way, Levels I, II, and III involve training and Levels IV, V, and VI involve education. In the three upper levels we see some overlap and correlation between the cognitive levels of analysis, synthesis, and evaluation and the corresponding levels in the other three domains. In any of the domains, these upper levels involve the application of the skills that were derived in the first three levels. It is these three upper levels that develop the decision-making and problem-solving attributes that are so highly valued in graduates of engineering and other professional schools. These are the attributes that are developed by engineering design experience.

These sophisticated skills require learning activities that have a component of individualized interaction with situations that are realistic, open-ended, complex, unstructured and perhaps even undefined. It requires a mental activity that is at the very top of Gagne's learning hierarchy, (Table 1.2), that is, problem solving or the application of principles. The learner is now put into an apprenticeship role to practice the implementation of his previously obtained skills. The professor's role at these learning levels is that of coach, mentor, master tuitor, consultant as opposed to the trainer-instructor role at the lower three levels of the heirarchy. Since the desired attributes obtained in learning activities in the upper levels of the taxonomy are essentially derived by involving the student in complex, problem solving, decision-making activities, it follows then that an experiential learning activity is a revelant and perhaps a necessary component of the learning program.

TABLE 1.1

COMPARISON OF THE TAXONOMIES OF LEARNING

LEVEL	COGNITIVE [1]	AFFECTIVE [2]	PSYCHOMOTOR [3]	EXPERIENTIAL [4]
I	Knowledge	Receiving (Attention)	Perception	Exposure (Comprehension)
II	Comprehension	Responding (Willingness)	Set (Willingness)	Participation (Application)
III	Application	Valuing (Acceptance) Commitment	Guided Response (Execution)	Identification (Involvement)
IV	Analysis	Organization (Importance)	Mechanical Response (Habitual)	Internalization (Adoption)
V	Synthesis	Characterization (Adoption)	Overt Response (Perfection)	Dissemination (Commitment)
VI	Evaluation			

[1] Bloom, B. S., et al., "Taxonomy of Educational Objectives Handbook: Cognitive Domain," McKay, New York, 1956.

[2] Wohl, K. Rath, et al., "Taxonomy of Educational Objectives Handbook: Affective Domain," McKay, New York, 1964.

[3] Simpson, E. J., "The Classification of Educational Objectives, Psychomotor Domain, " Project Report, University of Illinois, 1966.

[4] Steinaker, N. Bell, MR, "A Proposed Taxonomy of Educational Objectives: The Experiential Domain," Educational Technology, January, 1975, pp. 14 - 16.

Experiential Learning Objectives

A learning program that accommodates the upper three levels of the learning hierachy has the potential of accommodating and enhancing a large inventory of skills and attributes that are valued in a professional education. Each of the following are skills and attributes that can be reinforced by a well-designed experiential learning program:

problem-solving skills
interpersonal awareness
creative expression
communication skills
technical skills
self-confidence building
computation skills
engineering fundamentals
organizational skills
leadership skills
planning skills
professional ethics
engineering judgment

Any combination, or all these skills, can be program objectives when designing an experiential learning activity. They, in fact, represent a rather definitive attribute inventory for defining the desired competencies of a graduate engineer.

In addition to the inventory of attributes, there are several classes of operational skills that are enhanced by an experiential learning activity:

a. Ability to Reason

    How to do it - without knowing how to.
    How to go ahead anyway.
    How to derive alternatives.
    How to capitalize on your own resources, your colleagues, or any other source.
    How to make a decision and develop it.

b. Practicality

    How to be clever, shrewd, and right.
    How to cure cause rather than effect.
    How to make it simple and practical.
    How to do it low cost and on time.
    How to make it safe and reliable.
    How to make it saleable.

c. Teamwork
How to divide up the work.
How to get someone else to do it.
How to deal with people.
How to live with intelligence and stupidity.
How to give in and not lose.

d. Entrepreneurial Skills
How to capitalize on an opportunity.
How to negotiate and compromise.
How to be a developer.
How to get it done - anyway.
How to fail and win anyway.

e. Salesmanship
How to talk someone into it.
How to convince the skeptic.
How to get it funded.
How to make it believable.
How to tell them and show them.

TABLE 1.2
GAGNE'S LEARNING HIERARCHY

I	Response	Imitate
II	Association	Name
III	Discrimination	Select
IV	Behavior Chains	Order
V	Classification	Identify
VI	Principles	Apply a rule
VII	Problem Solving	Apply principles

Gagne, R. W., "The Conditions of Learning", N. Y., Holt Rinehart Winston, Inc., 1965.

All of these skills are valued for succeeding as a professional. All must be learned by involvement and experience. All are the interactive, interpersonal, communicative skills that an engineer must attain to be a successful achiever.

Typically, these skills are acquired "on-the-job" after schooling and the obtained degrees of proficiencies are randomly scattered and essentially accidental. These functional attributes are usually not consciously set as learning objectives within engineering degree programs. Yet, all are as essential to success as the technical skills of the engineering disciplines. An experiential learning activity can be designed to assure that the students have an opportunity to develop these attributes. The advantage of involvement during schooling is the opportunity to critique and diagnose the outcomes, "close-the-loop," and reinforce the successes.

Patterns of Involvement

The various models of experiential learning activities group into two classes: Simulations, and Authentic Involvement. Simulations consist of contrived situations that are carefully designed to meet selected learning objectives and are under close faculty control. The Authentic Involvement activities expose the student to real situations with totally open-ended outcomes, although the faculty may influence the selection of the situations and set performance criteria to assure that positive learning objectives are met.

Simulated experiential learning activities are almost totally classroom or laboratory based, originating with and managed by the faculty. They are a widely used learning activity. Thus, several models have emerged:

a. Experimental Laboratory - This is the most common model of experiential learning. Basically it involves an investigation either totally contrived by the instructor or jointly developed by the students and the instructor. It essentially focuses on or is limited to a particular apparatus, system, or instrumentation that is available or can be readily assembled in the laboratory. The activities may include testing new products, trouble shooting operational problems, designing and developing apparatus or instruments, exploring an idea, investigating the effects of parameter changes on a system, etc.

b. Guided Design - This is also a widely employed learning activity. It is centered on an instructor-contrived design situation. The students are involved in conducting a study and developing a solution. The solution may range from conceiving some feasible alternatives to the development of a complete design including analysis, dimensional synthesis, and shop drawings. Involvement ranges from step-by-step guidance by the instructor to achieve a predetermined solution to an open-ended competition between student teams judged by panels of practicing engineers. In all cases, the instructor establishes an explicit set of activities and criteria to assure specific learning outcomes.

c. Case Studies - Patterned after the case study methods pioneered in the management schools, these activities involve a role-play wherein the students are placed in a similar design situation to that of engineers in a real company. After the students have arrived at a solution, their decisions, results, or proposals are compared to the solution that was actually adopted by the company that had the problem. The instructor may draw upon a library of elaborately researched and documented case histories in the literature or develop cases from his own or colleagues' industrial experience.

d. Games - These activities involve live, interactive participation in continued simulations of design situations. The essential characteristic is that it simulates the dynamics of real situations by introducing additional parameters, constraints, or outcomes at each decision point. The simulator may be the instructor, or a team of instructors who provide the data dynamics, a computer model, or a game apparatus where new data and consequences are introduced by random techniques (roll of dice or drawing cards, etc.). The students may be in competition with each other to achieve the most favorable or desired outcome. The use of elaborate computer models has increased the potential of this type of experiential learning by providing a wide range of alternatives at each step based on rational data or computations.

Authentic Involvement activities are drawn completely from real, live, on-going situations. It always involves a "client" who has a real need to obtain a solution that has not yet been determined. The clients may be an industrial firm, a governmental agency, civic organization, an institution, or a private individual. The student may do all or part of the work on campus, or may be involved in periods of on-site activity, or full employment during the study. It may vary from a required, work experience with no faculty involvement to a total degree program commitment replacing all formal course work.

The most common and widely adopted Authentic Involvement activities in engineering have been the alternating work and study programs. The best known and are the classic cooperative education or "co-op" programs. There is, however, an increasing interest in other models of "real" involvement that has produced several innovative alternatives, including:

a. Internships - an on-site apprentice activity under the direct supervision of a practioner in the discipline. It usually involves a specified period of time with employment status while on leave from the academic program. It usually has little or no faculty involvement, academic content, or course credit. The placement of students is usually done by professional advisors who monitor the work experience to insure it meets the overall objectives. Internships are a required activity in Health and Teaching. They are optional in Engineering, varying widely from a few weeks summer employment, or several "work" sessions per week during one term, to alternating work and campus terms throughout a five-year period.

b Consulting - this class of activities involves a campus-based, faculty supervised, problem-solving experience, where all problems are solicited from an outside client. Students may be assigned to work on the problems individually or in teams. There is no student employment involved. The client may be asked to support minor direct costs, such as phone calls, clerical expenses and one or more student site visits. The students are in a role of a professional engineering consultant, the faculty in a role of "chief engineer." The project assignments may extend over more than one term but are usually confined to what can be done in one enrollment period. There is no obligation to provide an acceptable solution or meet any client deadline. The students present a written and oral report to the client at the end of the term with whatever results they were able to obtain.

c. Clinics or Design Centers - this is an on-campus, faculty administered, funded enterprise to undertake Engineering studies for sponsor-clients. It is an engineering design activity similar in operation to graduate level sponsored research projects. The Clinic or Center negotiates contracts to deliver a specified design, or study, or problem solution. Students are generally assigned in teams with upper classmen having project leadership responsibility. The students may be involved in all phases from proposal writing and contract negotiations to delivery of the final report. The funding may support all direct and indirect costs of the project although the students usually are not employed by the project since they receive course credit. The faculty have direct responsibility to the client to assure that contractual obligations are met.

Patterns of Operation

Experiential learning programs by their nature provide and open-ended opportunity for innovative operational styles. The overall objective of creating a broad spectrum of experiences for the student also provides a creative opportunity for the faculty in developing the entire package. Thus there is no standard operating procedure. Each is custom tailored to the circumstances surrounding the type of experience the model is to provide.

The simulation models tend to follow the classical academic procedures used for laboratory classes--i.e., regularly scheduled weekly class periods, instructor supervised activities, individual and team assignments, with most of the student's work accomplished during lab hours.

Since the Authentic Involvement models involve open-ended, unstructured activities, originating off-campus, the patterns of operation and student involvement may vary considerably. There is less need for faculty-dominated class meetings and organized activities. Most of the work is self-scheduled and self-paced by the students as demanded by their project. The involvement is more like an engineer's work pattern than a student's work pattern. The faculty member's role is more managerial and advisory than instructional.

How much experiential learning activity a degree program should contain is the source of great debate and perhaps some controversy. Some of the most innovative models are totally experiential with no formal courses or curriculum. The Co-op programs at the other extreme have little, if any, course involvement in the curriculum. Other programs may vary in credit-hour allocation from a minimum of two lab credits at the senior year to one or more course equivalents each term. The underlying objective is to provide a demand-to-know and a growth experience.

There is no "too soon to start" time since experiential learning begins at birth. The programs that employ experiential learning activities every year structure the rigor of involvement to match the levels of maturity as the student progresses. The existing programs demonstrate that it is possible to substitute experiential learning activities for formal course activities and still achieve the necessary and desired learning outcomes.

The student in experiential learning is subjected to a strong demand for self-management. The objective is to enhance enterprise, initiative, self-reliance, and resourcefulness by creating an environment that demands it. The activity schedule must be flexible enough to allow the student to plan and choose to suit their own needs and abilities as well as the demands of the project.

The role of the faculty member is primarily supervisory and advisory. He must manage the program to assure that the learning environment provides the opportunities for the student to gain the appropriate experiences to meet the desired objectives. Beyond that he should serve only as a consultant to the students and an evaluator of achievement. His role should be quite similar to the role he plays as supervisor of graduate students engaged in sponsored research.

One of the most important responsibilities a faculty member has is evaluation of performance. Evaluation of performance in experiential learning is far more challenging than in formal instruction. The very nature of the activities emphasizes performances that will inevitably demand subjective assessment. Two needs must be served: to provide an on-going critique and reinforcement (feed-back), and to provide a terminal assessment of competency and accomplishment (closure).

There are two basic principles that must be employed in conducting the evaluation process: define the learning outcomes to be achieved, and state how the rating or assessment will be determined. The greated sin of all is to keep it a secret from the learner.

Since this type of learning is so complex and the outcomes are essentially performance-based, it will be necessary to rely on the subjective opinions of as many observers as possible. Rating sheets, listing all the attributes to be assessed, should be periodically solicited from the student's teammates, from the supervising faculty and clients, including a self-assessment from each student. Periodic written and oral progress reports should be critiqued by panels of students, faculty, and professional consultants and/or clients.

The terminal competency assessment should provide two kinds of information: a profile of the student's relative abilities in the various performance attributes defined for the learning experience, and an overall summative ranking or judgment of his contribution and ability to do. The profile is a collective judgment of operational strengths and weaknesses. The summative judgment may be a ranking in his class, a letter grade, or some defined index of relativity to compare him to his competition and gauge his potential.

An effective assessment system is crucial to a successful experiential learning-program. The most useful guideline to use in constructing an effective evaluation procedure is to equate it as closely as possible to the techniques and procedures associated with good management practice in industry. The crux of these procedures is that both employer and employee are in the act - both agree on the ground rules - and both contribute to process.

The Outcomes

An experiential learning activity provides a number of opportunities and fringe benefits in addition to its programmed objectives. Each model offers different outcomes, but, in general, a well managed activity, expecially when it contains an authentic involvement component, has an impact on the learner and the faculty. There is, for the student, an environment rich in excitement, high in motivation, and challenge. The authenticity of the experience has a noticeable maturing effect and develops a strong sense of self-concept and confidence. The open-endedness and the obvious awareness that the problem requires a solution that neither the client nor the instructor is aware of, creates a demand for creative and innovative action. The magnitude, complexity, and challenge demand leadership, planning, and self-management, and an ability to accept failure and seek alternatives. There is a development of professional value systems and an engineering attitude that cannot be obtained in a classroom.

Experiential activity creates opportunities and a justification for the utilization of self-learning resources. There are inbuilt opportunities for students to study the literature for new information, and to undertake self-study of techniques and background information not available in the required curriculum. It creates an environment of self-managed learning - the necessity for life-long learning. There is a broadening of awareness that encourages study in areas peripheral to the degree discipline.

In the development of programs where the experiential component dominates the degree program, there are program objectives for generalization and education of the complete man. An underlying conceptualization evolves that learning-to-learn and being able to apply what is learned is what education is really about.

The faculty who engage in experiential learning management find that the change in role from "instructor" to "supervisor-consultant" opens up new creative opportunities in educational innovation, professional counseling, management and consulting.

In a nutshell, experiential learning is a necessary, though not sufficient, component of the educational process. There are two phases in the educational process: inputting (learning information and techniques), and outputting (sythesis, analysis, and decision making). The formalized instructional processes take care of the inputting; experiential learning develops the outputting.

2

The Program Evaluation Process

Different experienced-based programs have been created to concentrate on new learning outcomes--especially those in the upper ranges of various learning hierarchies and those most necessary for practicing engineers. These departures from traditional classroom and laboratory curricula stimulate curiosity and create high expectations. What are the features of exemplary experiential programs and how do they actually work? Where do they fit into the traditional curriculum? Are new learning outcomes really accomplished and how well? What programs require more effort and resources than traditional approaches? Generally, what impact on students, faculty and the institution results from experience-based learning? These questions shaped the purposes and conduct of this study.

Purposes and Philosophy

Several objectives were set in the development of the study. First, the study was designed to describe, in some detail, the structure and activities of engineering programs exemplifying different approaches to experiential learning. Second, the learning outcomes of this approach needed identification, especially in comparison to the regular curriculum. Next, the activities producing these outcomes needed exploration and more precise identification. Finally, the broad impact of experiential learning on student and faculty roles and on the institution needed clarification.

The purposes could best be met through a systematic, analytical and comparative study producing both qualitative and quantitative information to clarify what experiential engineering education is in general and the program alternatives are in particular. By design, the study was exploratory, satisfying certain curiosities and stimulating others, yet testing no hypotheses. The intent was to establish a basis for judgement and decision about the role experiential learning should play in higher education.

Design and Methodology

Given this general approach, six different programs or models of experiential education were chosen. Each program either exemplified an established and successful experiential model or represented a unique approach to experiential learning. The institutions chosen were: the University of Cincinnati, Harvey Mudd College, Kansas State University, representing the oldest and most institutionalized programs, and Worcester Polytechnic Institute, the University of West Virginia and the University of Massachusetts, representing the newest and most experimental programs.

With this sample of institutions, significant participating groups--students, faculty, administrators and clients--were identified from which interviewees could be chosen. The exploratory purpose and limited scope of the study suggested choosing interviewees who could articulate their experiences and provide perspective on the program. Students were chosen who were at different stages in the curriculum, and alumni were identified who had been graduated with the previous five years. Faculty with a great deal of and with little experience in the program were chosen and, when possible, a faculty member who was critical of the program, was interviewed. Program clients and key administrators presidents, deans, department heads, and program coordinators were asked to participate depending on their involvement. Therefore, interviewees were chosen purposively because of the insights they might offer, rather than randomly, to insure representativeness of opinion. The study boasts no claims for generalizability. Table 2.1 identifies the number of interviewees for each institution.

TABLE 2.1

PARTICIPANTS INTERVIEWED

	Admin	Student	Alum	Faculty	Client	Total
UWV	4	10	3	10	0	27
HMC	4	11	2	7	4	28
WPI	5	12	0	6	5	28
U-Cinn	1	7	5	6	4	23
U-Mass	4	10	1	4	6	25
KSU	3	12	3	6	3	27
TOTALS	21	62	14	39	22	157

Instrumented interviews were developed for each group and focused on their particular relationship to the program. General questions were asked of all interviewees. Other questions were asked of only certain categories of participants. Generally, each hour-long interview was designed:

a. to obtain a description of the program's objectives, activities and outcomes;
b. to gather personal reactions to various aspects of the program;
c. to collect evaluative information on the strengths, weaknesses and possible improvements.

In addition to interview data, published information on the program was gathered in advance on the site visits and additional materials were collected after visiting the programs. In essence, the study attempted to "photograph" experiential programs from various perspectives with both wide-angle and telephoto lenses.

Campus Visits

Three project team members visited each institution for an intensive two days of hour-long interviews. Site visits were facilitated by a project coordinator at each institution who contacted interviewees and arranged schedules. The first day began with a meeting of program leaders in which the purposes of the study were explained. Conversation in this meeting also provided the research team with details and insights of the program to supplement what had previously been gathered from catalogues and other descriptive literature. After the interviews were concluded, the two-day visit closed with a feedback session to the concerned and involved institutional representatives. At this meeting, team members shared initial impressions and clarified any questions that arose during the interviews.

Limitations and Merits of the Study

The merits and limitations of all evaluative studies are shaped by purposes and constraints and produced results reflecting these conditions. This study has substantial limitations in some areas which should be noted before interpreting the results. The major limitation concerns the purposive, not random, selection of interviewees. Therefore, data presented for various constituencies cannot be generalized to the entire constituency. Interpretations from interview instruments, in particular the Learning Inventory, Program Inventory, and Satisfaction Levels, can only be regarded as suggestive and are in no way intended to be definitive. The data reflect the biases of the particular individuals interviewed--usually a positive bias toward experiential learning. Also, these data come primarily from the self-reports of program participants, not observed behavior or tested knowledge. Some items on the instruments--such as the Learning Inventory--are imprecise, yet their use in the Analysis and Summary may mask this imprecision. Additionally, the program was not viewed from all perspectives, i.e., from those of non-participating faculty members or students or from those that left the program or were unsuccessful in it. Lastly, the numbers presented in the reports which follow suggest greater precision than actually exists. This methodology, however, serves to suggest important differences and similarities which are difficult to spot without some quantification. Thus, data trends and patterns, rather than statistically significant differences, are identified and discussed.

Limitations of sample selection, data sources, and measurement are balanced by a comprehensive and in-depth exploration of the programs obtained from people who could articulate their experiences and attitudes. Therefore, the reports provide descriptive information on program activities plus suggestive information on important teaching/learning outcomes and relationships. Many of these issues need further research. Hopefully, however, this study may provide clues and insights for teachers and administrators considering experiential programs and for researchers investigating the dynamics of the teaching/learning process.

Organization of the Report

The following chapters present the findings of this study. The six programs are discussed in a similar format and in the order of their founding which covers the period of 1906 (University of Cincinnati) to 1973 (University of Massachusetts). The first three programs have relatively long experience and are well known, while the last three programs are recent innovations in experiential learning. The two concluding chapters summarize, compare, and speculate.

In each of the six chapters on institutional programs the program's major features and general purposes are documented first. General purposes become more specific through a discussion of the learning and skills which program participants deemed most important for practicing engineers. Next, student learning outcomes for both the experiential and traditional components of the curriculum are discussed and contrasted. The "traditional" curriculum varies from campus to campus. Generally, it refers to classroom and laboratory teaching and learning, but includes all learning experiences not a part of the experiential program. Following the discussion of learning outcomes, the learning system (i.e., important teaching/learning activities and relationships) is described. The learning system accounts for many of the outcomes and points to the most significant elements of experiential learning. Next, new teaching/learning roles are discussed. This section describes the changes in resource requirements required to conduct the learning activity. Program results, sometimes unintended and in addition to student learning, are pinpointed in the next to last section. The strengths, weaknesses and future challenges of the particular program are presented in the summary and concluding section.

3

The University of Cincinnati Professional Practice Program

The Professional Practice Program at the University of Cincinnati is designed to enrich a student's learning and sharpen career choices through alternating study with employment. Student counseling and placement are performed by a professional staff. Students are placed off-campus for as many as seven quarters by alternating a study quarter with a work quarter during the second, third and fourth years. The degree program lasts five years. Student employment compensation increases with the student's responsibilities.

History

The University of Cincinnati, founded in 1819 with the establishment of Cincinnati College and the Medical College of Ohio, became a University in 1870 through an act of the City of Cincinnati. It is the nation's first municipally-sponsored, state-affiliated university and is the second largest municiple institution in the country. The College of Engineering began its cooperative program in 1906 under Dean Herman Schneider's leadership.

Program Description

The co-op program currently called the "professional practice program" is mandatory for students in the Colleges of Engineering, and the College of Design, Architecture, and Art. It is optional for students in the College of Business Administration. Over 3000 students are enrolled in the program and nearly 1800 of these are engineering students. More than 1000 firms and agencies cooperate with the University by offering students work experience opportunities. Professional career counselors, organized in the Office of Professional Development which is independent of the three participating colleges, administer the program. The director serves on an executive board which governs the program whose members include the Vice-Provost for

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Academic Affairs and the deans of the three participating colleges.

Students first enter the program through a one credit course--Professional Development I--taken their first year. The course facilitates career planning through descriptions of career possibilities and encouragement of self-analysis. After completing the course, students are advised by a career Development Counselor on possibilities for their initial placement. Students can interview for several placements and choose among their offers. Their choices are based on the type of career desired combined within the student's engineering speciality. Generally, students in engineering are encouraged to stay with one company which may involve as many as seven placements, successively progressing into positions of greater responsibility. Students finish their co-op experience with a final course, Professional Development II, which facilitates the job-seeking process.

Program Purposes

The general purposes of the program are listed in the University of Cincinnati Bulletin:

> The Professional Practice Program offers the student an opportunity for selected practical experience purposely intermingled with a gradually expanding academic background. Thus, students obtain first-hand knowledge of professional practices and opportunities. The professional practice assignments assist each student in developing an understanding of human relationships and in learning to work with others as a team. His individual growth during his practice experience is enhanced by the realization that, in addition to demonstrating his theoretical knowledge, he is developing the supplementary skills and attitudes possessed by professionals in his field. Participation in the program enables the student to make a more intelligent selection of graduate position. As a graduate, his professional practice experience makes him more valuable to an employer and increases his qualification for a more responsible career assignment.

An assessment of the general purposes and the relative importance of student learning outcomes is presented in Table 3.1. All the outcomes are perceived to fall between crucially (4.0) and very important (3.0). However, five learnings - engineering judgment (3.8), communication skills (3.8), problem-solving skills (3.7), planning skills (3.6) and professional ethics (3.5) received scores of 3.5 or above. Generally, there is concensus on the importance of these skills across the three groups - students, faculty and alums. The exception is planning skills which are emphasized more by students than by the alums or faculty.

TABLE 3.1

LEARNING INVENTORY
UNIVERSITY OF CINCINNATI

Personal Opinion of the Importance of the Skill or Quality

	All N=18	Stud N=7	Fac N=6	Alum N=5
Problem-solving skills	3.7	3.7	3.8	3.4
Interpersonal awareness ..	3.3	3.3	3.3	3.2
Creative expression	3.3	3.1	3.3	3.6
Communication skills	3.8	3.9	3.7	3.8
Technical skills	3.4	3.3	3.3	3.8
Self-confidence building ..	3.4	3.6	3.0	3.6
Computation skills	3.0	3.0	3.2	2.8
Engineering fundamentals .	3.4	3.1	3.7	3.6
Organizational skills......	3.3	3.6	3.0	3.2
Leadership skills	3.4	3.6	3.3	3.2
Planning skills	3.6	3.9	3.3	3.4
Professional ethics	3.5	3.7	3.5	3.2
Engineering judgment	3.8	3.9	3.7	3.8

Importance Scale:

Crucially important = 4; very important = 3; somewhat important = 2; not too important = 1.

As an interesting aside, several outcomes are viewed quite differently by the three groups. Table 3.1A summarizes the items on which the largest differences occur. These data suggest that one's role strongly influences one's perceptions.

Table 3.1A
Importance Differences by Group

Creative expression	Alums rated higher than stud & fac
Technical skills	Alums rated higher than stud & fac
Self-conf. building	Stud & alums rated higher than fac
Engineering fundamentals	Alums & fac rated higher than stud
Organizational skills	Stud rated higher than fac or alum
Professional ethics	Stud & fac rated higher than alum

Program Outcomes

Surveying the importance of outcomes provides perspective for: 1) an assessment of whether that outcome is available or taught in either the experiential component or the regular curriculum; and 2) an assessment of the quality of the learning. Table 3.2 provides data related to this assessment.

Generally, program participants thought that both the experience component and the regular curriculum provided developmental opportunities for all the outcomes. The co-op program was created to accomplish certain objectives which the regular curriculum was not designed to accomplish. Data on the quality of experiences in the co-op and regular portions of the curriculum suggest this is happening. Participants thought that the experience component was more effective on eight of the items, was on par with the regular curriculum for three items and that the regular curriculum was more effective for two items engineering fundamentals and computation skills. Of the five most important skills (Table 3.1), three - communication skills, professional ethics and engineering judgment - are learned more effectively in the experience component, while the remaining two problem-solving and planning are handled equally well in both curricula.

Seven items received quality ratings between excellent (5.0) and very good (4.0) in the experience curriculum. Four items received similar ratings in the regular curriculum. Engineering fundamentals in the regular curriculum received the highest quality rating (4.6) for either curriculum. Four areas stand out in either the students' or faculties' minds as exceptional, i.e., ratings of 4.5 or above. Faculty rated both interpersonal awareness and self-confidence building as 4.8 in the experience component. They gave a 5.0 rating to engineering fundamentals and a 4.5 to technical skills and 4.6 to both self-confidence building in the experience component and engineering

TABLE 3.2

LEARNING INVENTORY – UNIVERSITY OF CINCINNATI

Skill or Characteristic	EXPERIENTIAL PROGRAM						TRADITIONAL PROGRAM					
	Existence of Developmental Opportunity		Average Quality Rating				Existence of Developmental Opportunity		Average Quality Rating			
	Yes	No	All	Stud	Fac	Alum	Yes	No	All	Stud	Fac	Alum
Problem-solving skills . . .	18	0	4.1	4.0	4.5	4.0	18	0	4.2	4.3	4.2	4.0
Interpersonal awareness .	18	0	4.3	4.4	4.8	3.6	16	2	2.9	3.0	3.2	2.4
Creative expression	17	1	3.6	3.6	3.4	3.8	17	1	3.1	3.2	3.2	2.8
Communication skills . . .	18	0	3.9	4.3	3.7	3.6	16	2	3.1	3.2	3.6	2.4
Technical skills	18	0	4.0	3.6	4.2	4.4	18	0	4.1	4.1	4.5	3.4
Self-confidence building .	17	0	4.4	4.6	4.8	3.8	17	0	3.5	4.0	2.8	3.9
Computation skills	18	0	3.2	3.0	3.8	3.0	18	0	4.4	4.3	4.4	4.4
Engineering fundamentals	17	1	3.4	3.0	3.8	3.6	18	0	4.6	4.6	5.0	4.4
Organizational skills	17	1	4.0	4.1	4.0	3.8	15	3	3.3	3.4	3.0	3.4
Leadership skills	17	0	4.1	4.3	4.9	3.4	16	2	2.9	3.0	2.8	3.0
Planning skills	17	0	3.9	4.3	4.0	3.4	17	1	3.8	3.9	4.0	3.4
Professional ethics	17	1	3.6	3.9	3.4	3.3	16	2	2.7	2.7	2.8	2.8
Engineering judgment . . .	18	0	4.2	4.3	4.2	4.2	18	0	3.1	3.0	3.9	2.8
			n =	n =	n =	n =			n =	n =	n =	n =

Quality Scale:

Excellent = 5; very good = 4; good = 3; fair = 2; poor = 1

fundamentals in the regular curriculum. It is interesting to note that for the five most important skills only two of them, engineering judgment and problem-solving skills, received average quality ratings of very good (4.0) or above in either of the two curricula. This suggests that more effort could profitably be spent in the remaining most important areas--communication skills, planning skills and professional ethics.

Generally, the three groups viewed the quality of the two programs similarily. Two exceptions exist. Students believe problem-solving skill development is better in the regular curriculum. Faculty believe the opposite. However, the nature of problems vary between the two curricula. Both faculty and students believe that technical skills are best developed in the regular curriculum while the alums thought the experience component did a better job of technical skill development

The Learning System

What elements of the experience component make it a powerful learning system? Several stand out. First, experience is truly "real world." Students work in natural engineering settings with the job and interpersonal stimulation that a company situation provides. They have chosen a job assignment freely with the guidance of a professional career advisor. They progress from simple to complex assignments as their knowledge grows, building self-confidence in the process. Their tasks vary in complexity and responsibility, but in general. The last placement assignment involves design and/or project operation responsibility.

Secondly, the program has "built-in" motivators and quality controls. Students are motivated both intrinsically and extrinsically. The program is geared to one of their fundamental interests--an engineering career. Both words are important. They can be challenged by the engineering tasks put before them, by the prospects of employment after graduation, and by salary advances through the progression of their placements. The career development counselors are motivated because of the special and multi-faceted nature of their work and the inherent benefit they see in facilitating student development. Clients are motivated because they receive competent student employees, can control an effective training program and contribute to the engineering profession through the development of better trained students.

Quality control is built into the program in two major ways. First of all, career development counselors receive both systematic and periodic evaluation from the students' supervisor and from the student when the student completes a work term. These evaluations provide information on both the company and student. Counselors also receive information from on-site field visits to company locations. Counselors attempt to visit companies once a year. Secondly, many companies have a long history of working with the University of

Cincinnati. The wrinkles have been worked out of the program. In some instances, a co-op graduate becomes the supervisor of a co-op student, further enhancing shared expectations and purposes regarding the co-op experience.

A third powerful teaching/learning element is student interaction with career development faculty and on-the-job supervisors. This interaction is specifically designed to enhance a student's professional career development. The counseling of students about their careers and their placement is handled almost exclusively by their career development counselors not by engineering faculty members. While engineering faculty members definitely support the program they have little to do with its design or operation. Specific academic objectives are not filtered into the co-op experience. Students contact the co-op program regarding their first placement and then in an assessment interview after each work term. Students report that they interact most intensely with their on-the-job peers and a designated supervisor. This supervisor has special responsibilities designed into the companies's participation in the program. Responsibilities focus primarily on assessment of student performance and professional growth. Generally, the students interviewed were highly satisfied with relationships with their supervising professors, i.e., career development counselors (3.8 on a 4.0 scale) and with their clients (3.6 on a 4.0 scale).

The assessment process, itself, is an important part of this learning system and derives from two assessment sources; the job supervisors and the students. All supervisors are requested to give students feedback on the job and submit to the career counselor a comprehensive assessment of student performance and professional development. Students systematically reflect upon their experiences and development after each work term, fill out a detailed evaluation form and debrief their experience with their counselor. Ideally, the counselor utilizes the information from the supervisor and student to evaluate the student's progress and suggest areas for development.

Over the years, the assessment process has been carefully worked out and is highly formalized. On-the-job supervisors evaluate student performance in three areas: 1) position performance, i.e., quality of work, communication effectiveness, creativity; 2) work habits, that is, organization, initiative, responsibility; 3) problem areas, including technical ability, immaturity, personality problems, attitude.

Supervisors use scales in making their assessments and are requested to make comments and use examples. Therefore, the evaluation definitely facilitates student development. Supervisors also assess the students' professional development. They are asked to identify positive and negative personal characteristics, such as, business maturity, personal appearance, honesty, leadership abilities. Further, they are asked if the student is making satisfactory progress for his stage of development and, if he isn't, to explain why. Also, the supervisor is asked to offer suggestions for the student's

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professional development. This evaluation process identifies those qualities deemed important for a practicing engineer to possess. Students have developmental targets and receive feedback on progress.

Students are also required to evaluate their positions and themselves. Comments are requested on a variety of topics, such as:

1. General responsibilities in the department.
2. Determine the major duties comprising your assignment and describe each as a separately numbered item in descending order of complexity and importance. In a final paragraph, describe how your work contributed directly to fulfilling the general departmental responsibilities listed above.
3. Describe the professional skills you have acquired or utilized through this practice assignment. Consider such skill areas as: professional relationships; proposal and report preparation; visual communication; creative application of media; collection analysis; interpretation and projection of empirical data; oral and written communications; equipment design; selection and start-up; and any other areas which you recognize as pertinent to your profession.

In addition to these comments, students are asked to complete a position appraisal adapted from "Role of Human Relations Analysis in Management Engineering Activities" by James Breanas in **Personnel Journal**, vol 48, Sept. 1969. The items seek the student's appraisal of his supervisor, his co-workers and himself.

The student report provides a sound vehicle for personal reflection and job analysis which can contribute to personal and professional growth. Generally, students responded favorably to questions on the assessment process. Five of seven students were aware of the criteria for evaluation before they began the work term. Obviously, over several terms, the criteria became explicit through the feedback process. Students rated their satisfaction with the assessment process as a 3.3 on a four point scale.[2] The trend of student comment for those not responding "very satisfied" was that the system was unevenly administered or under-utilized. Sometimes a supervisor would not fill out the form or their contact with their counselor was not lengthy enough. Counselor work loads are tremendous. Each counselor is responsible for about 300 students.

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[2] 4 = very satisfied; 3 = satisfied; 2 = dissatisfied; 1 = very dissatisfied.

New Learning/Teaching Roles

The Cincinnati system spreads responsibility for the teaching/learning process. Departmental faculty have no formal responsibility for student learning in the experiential component. In essence, learning objectives are articulated through the assessment process which is professional development oriented and managed by a professional development counselor. The counselor role is just that---a personal advisor and counselor---not an academic mentor. As the learning inventory, Table 3.2 demonstrates, similar learning objectives are part of both the regular and work components of the curriculum. However, many of the most important learning objectives (Table 3.1) are best handled (Table 3.2) through the work experience.

Responsibility is spread also to the on-the-job supervisor. This individual can structure employment as a progressive learning experience and is responsible for feedback to the student. Interview data indicates that this particular role is most important to students as they reflect on their co-op experience.

The student learning role changes considerably as well. Less than half of the students interviewed reported that they were aware of the skills expected of them when they began. The work term becomes an open-ended challenge. The learning environment shifts from an academic setting of classrooms, labs, books with right-answer questions and student peers to a company setting with a range of people and tasks, a nonacademic schedule and problems with more than one solution. Student relationships and responsibilities are new and different Rewards are different as well--solving real problems, co-worker and supervisory approval, productive human work relationships. It's little wonder that students report gains in self-confidence.

The spread of teaching/learning responsibility has fostered the development of an elaborate career development program. Housed in a nicely appointed Career Dynamics Center, career development counselors and placement officers work cooperatively to relate the world of work with the world of study. These essentially new teaching functions create additional costs for the university, forcing justifications for program results.

Additional Outcomes

The purely educational outcomes for students mentioned so far do not tell the whole story of the Professional Practice Program. Faculty members benefit in personal ways. Two of the three professional practice faculty mentioned the satisfaction they gained from facilitating student growth. One also focused on the stimulating environment of being in close contact with practicing engineers and academics. One of the three academic faculty members interviewed mentioned that, especially because of his small department, classes were enriched. He could discuss real world problems with students and thereby remain current with practical problems.

Clients report three kinds of benefits. First, the program provides prospective employees to both train and evaluate. Secondly, their companies are providing a service, through "real life" exposure of students, to the engineering profession. Lastly, co-op students provide on-going and flexible person-power for their organizations.

Benefits, in addition to their learning, accrue to students. Obviously, but importantly, they earn money for their education. Some students also mentioned a certain sense of pride that went along with earning and paying in this way. Working and earning also fosters a more realistic impression of engineering. Students unanimously stated that they had a more realistic impression of engineering and engineers because of participation. This realism also promoted more positive attitudes toward engineering and engineers. Eight of twelve respondents said they had more positive attitudes, two said their impressions were about the same and two more were undecided. The work term exposure positively affected their commitment to engineering. Of the seven students responding, five indicated more commitment, one indicated no effect on commitment and one student wasn't sure.

After reflecting on many aspects of their co-op experience--evaluation and assessment, relationships with professors and clients, benefits, disadvantages and whatever else they deemed important--all the students indicated they were very satisfied with the Co-op experience (4.0 on a 4-1 satisfaction scale). Therefore, the entire Professional Practice Program provides a highly satisfying student experience.

Participation in the program is, however, not without some disadvantages. Some students noted that the program lasted five years, therefore, their entry into full-time employment was delayed by a year. Two faculty members wondered if participation in the co-op program didn't divert energy or interest from academic careers. One faculty member said he had heard complaints from married students about having to relocate every few months. Also, the full-year calendar had been mentioned to him as a sore spot.

Summary and Conclusion

Alternating on-the-job employment with classroom and laboratory academic preparation makes Cincinnati unique among the programs investigated for this study. It is, however, typical of the co-op approach used in a large number of institutions. Teaching responsibility has been diffused because of these parallel activities. A philosophy of career development, in addition to academic development, undergirds this program. Therefore, new learning objectives have been developed which foster the student's development as a person in the role of professional engineer. Responsibility for insuring that these objectives are met rests with a career development counselor--a different and emerging pedagogical role as it is conceived at Cincinnati.

Given this distinctive characteristics, how do program participants--alums, students, faculty and clients--view this program's strengths and weaknesses? Students and alums recognized the major strength as a comprehensive exposure to engineering and its possibilities for them as developing engineering. They learned much about engineering and about themselves--their skills, interests and ideals. Interpersonal skill development was also viewed as an important strength of the program, e.g., cooperation, communication, leadership. Earning a living while studying was also mentioned as being especially important to some students. Site-visit team members also sensed that students valued the rhythm of study and work. These life and learning styles seemed to balance themselves to the student's satisfaction. Some looked forward to leaving work for academe just as they anticipated getting back to the job after weeks in the university setting.

The faculty (career development counselors and professors) noted that the program's strength lay in providing a truly comprehensive engineering education--personal growth and maturation, the opportunity to relate theory and practice and the chance to begin a career with a broad base of knowledge.

Strengths from the clients' viewpoints focused on the quality of both the students and the program's administration. One client valued the long history of good working relationships with both the professors and the counselors.

In addition to identifying strengths, program participants were asked about weaknesses. Clients didn't spot many problems--one suggested stronger business and computer orientations among students and another noted that he had an overload of students during the summer.

Career development faculty members noted that because of workload pressures, company by company, student by student, the program was unevenly administered. Sometimes students weren't placed in demanding enough assignments and one faculty member sought more interaction, generally, between supervisors and faculty members. Another respondent noted that good students tend to go right into a career rather than pursue advanced work and still another sought a longitudinal study of the program to truly identify its impact on individual career management.

Generally, the feeling of confinement to a single company is one weakness emerging from student interviews. They felt a need for additional exposure and felt both limited and sterotyped because of work with one company in one engineering area. Another group of weaknesses pointed to refinements; in the supervisory rating procedure, in providing more information before the first placement, and in the availability of good job experience matched with student needs. One student mentioned that returning to the University in the summer, when it was not really in full swing, limited his education because of fewer offerings in arts and sciences, no student newspaper, and restricted medical service.

Suggested improvements and challenges for the future focus on overcoming weaknesses. Students would like to see the possibility of more than one placement. While shifts are possible, they are not encouraged. Career development counselors see the quality of their service caught in the current fiscal crunch. They also see challenges ahead in better involving the academic faculty in the program. The clients interviewed see no pressing areas for improvement.

Generally, the comments are testimony to a well-conceived and smooth-running program with a long and successful history which has built-in sources of quality control and refinement. This program admirably exemplifies the ''co-op'' notion for professional education as it has evolved over the years.

4

The Harvey Mudd College Clinic Program

The Engineering Clinic, or experience portion of the curriculum, was begun in the early 1960's and is now a mature program solving problems unique to Harvey Mudd but which exemplify broader engineering and professional educational concerns. Harvey Mudd faculty members wanted to offer students a real world engineering experience with all the learnings inherent in "the real world." They recognized that faculty were often divorced from practice save occasional summer consulting.

Alternate solutions were explored--cooperative education, the practice school approach and clinical training models in other professions are examples of the alternatives considered. Harvey Mudd synthesized elements of these approaches to create "a primarily campus-based, team-centered, funded, open-ended, problem-solving experience" entitled the "Engineering Clinic." These experiences flow from projects generated by local, state-wide or national firms or agencies who look to Harvey Mudd for high quality work at limited expense.

History

Harvey Mudd College was founded in 1955 and became the fourth of five small private colleges known as The Claremont Colleges. Located 35 miles east of Los Angeles, just below Mt. Baldy, the highest of the San Gabriels, the Colleges maintain their distinctiveness while benefiting from integrated services and a common philosophy. Harvey Mudd concentrates on four undergraduate majors--chemistry, engineering, mathematics and physics. Students can spend a fifth year earning a Master of Engineering degree.

Harvey Mudd College pioneered a fresh approach to educating engineers and scientists when its doors opened in 1957. The College wanted its students to recognize "that technology divorced from humanity is worse than no technology at all." As a result, students take one-third of their course work in the humanities and social sciences. This is the highest percentage of non-engineering related course work for any accredited engineering college in the country.

Academic selectivity characterizes all the Claremont Colleges. Most of Harvey Mudd's 400 students (86% of 1974 entering class) graduate in the top 10% of their high school class. The majority come from California. They have especially high College Board scores (600's and 700's) and receive enthusiastic recommendations from their high schools. Approximately twenty-five to thirty percent of the student body majors in engineering.

Program Description

Students must participate in the engineering clinic generally during their junior and senior years. Each semester's activity is graded and worth three credits. Fifth year masters students also participate in the clinic as project leaders, earning six units per semester. While student participation in the clinic is mandatory, students choose their particular project in consultation with the project director. Students report that their selection decisions are influenced by: 1) the substance of the project; and 2) the professor and team members potentially or actually involved in the work. Student choice seems to positively influence student motivation. Projects are recruited in various ways and selected with important learning criteria in mind. All projects are funded. Each client is charged a standard fee which covers direct and administrative costs. The students are not paid to work on the project.

A good project according to those involved is one which emphasizes the application of theory, involves engineering design work and necessitates a team approach. Projects tend to be longer than a semester; therefore, students often flow in and out. Some students never see the project from beginning to end. Projects involving substantial amounts of menial work are screened out. In general, the projects are rigorous and comparable to graduate level sophistication.

Student/faculty/client interactions have both formal and informal dimensions. Formally, the client presents a general problem to the clinic. Students, led by a fifth year student and with faculty supervision, develop a proposal which is shared and negotiated with the client. Once the proposal is accepted, periodic team meetings with and without the faculty member take place. Progress is reviewed, plans are made and responsibilities are detailed. Sometimes students visit the client or vice-versa depending on the nature of the task and the client's location. The team is responsible for a project presentation to the entire Clinic in the college auditorium. The Clinic faculty and students currently participating in projects offer critiques of methodology, analysis and solutions. Students must formally prepare for these sessions and three members of the audience are responsible for written feedback on the presentation. Lastly, the team produces a written report for the client at project's end.

Informally, students use faculty members as resources, involving engineering and other faculty who can best contribute to their projects. Naturally, their supervising professor is their primary resource. He was chosen because of his competence for the particular project.

Program Objectives

The Clinic is designed as a rich experience facilitating the personal and professional growth of the student while benefiting the faculty and the College in the process. More specifically, the objectives have been articulated in a student guidebook as follows:

> You probably suspected that the Clinic was designed to do more than solve someone else's technical problems. It is also aimed at helping you develop as a person and as an engineer, and at the same time supporting the school.
>
> Thus the objectives of the Clinic may be viewed as threefold:
>
> First, to develop the individual as a person by
>
> - increasing his awareness of his strengths and weaknesses and providing a context for growth;
> - increasing effectiveness in group interactions;
> - reinforcing an acceptance of responsibility for his actions;
> - building leadership and communication skills.
>
> Next, to train the individual as an engineer by
>
> - increasing his technical knowledge and skills, especially those related to the engineering design process;
> - providing practical experience in the application of knowledge and skills;
> - helping him to recognize and deal with resource limitations as well as with legal and managerial constraints;
> - encouraging an inquiring attitude and non-stereotyped responses.
>
> Finally, to support the College by
>
> - encouraging outside support for Clinic programs and for the College in general;
> - fostering interdisciplinary communication and cooperation;
> - maintaining an awareness of state-of-the-art developments.
>
> If these objectives are met, it will benefit you, the Clinic, and HMC. While participating in your project, check to see how well things are going in terms of these goals. If you don't think the objectives are being met, DO something about it.

The program goals stated above came from public documents and are broad in perspective. In an attempt to focus these goals, program participants were asked to rate the importance of various student learning outcomes. The results of this scaling, presented in Table 4.1, demonstrate that all the learning outcomes are important. However, some are viewed as relatively more important than others. Also different groups attach different significances to what learnings are important.

TABLE 4.1

HARVEY MUDD COLLEGE

IMPORTANCE OF ATTAINING THESE SKILLS

Constituency Group Average

	All	Student	Faculty	Alumni
Problem-solving skills	3.8	3.6	4.0	4.0
Interpersonal awareness ...	3.1	3.2	2.9	4.0
Creative expression	3.0	2.7	3.3	3.5
Communication skills	3.5	3.5	3.4	3.5
Technical skills	3.1	2.8	3.6	3.0
Self-confidence building ...	3.1	3.0	3.0	3.5
Computation skills	2.5	2.1	3.0	3.0
Engineering fundamentals ..	3.5	3.3	3.6	4.0
Organizational skills	3.4	3.6	2.9	4.0
Leadership skills	3.3	3.4	2.9	4.0
Planning skills	3.4	3.6	3.0	4.0
Professional ethics	3.2	2.9	3.6	3.5
Engineering judgment	3.5	3.2	3.7	4.0
	n = 21*	n = 11	n = 7	n = 2

* This number includes one administrator not included under faculty.

Importance scale:

Crucially important = 4; very important = 3; somewhat important = 2; not too important = 1.

Faculty give ratings of above 3.5 on the 4.0 scale to: problem-solving skills (4.0), engineering judgment (3.7), professional ethics (3.6), engineering fundamentals (3.6), and technical skills (3.6). For students the most important skills, those above a 3.5 were: problem-solving skills (3.6), organizational skills (3.6), planning skills (3.6) and communication skills (3.5). While there is agreement on the relative importance for problem-solving and communication skills, the data indicate somewhat different perspectives on the other skills. By ranking the importance of the skills, it can be noted that students place organizational skills and planning skills near the top while faculty place them near the bottom. The opposite is true for technical skills which faculty rank high and students rank low. These differences illustrate the difficulty of precisely matching expectations in a complex learning envirounment even in a small college. Not only do group variations exist but on some outcomes the range of opinion within a group across the scale is wide.

Program Outcomes

The scaling of importance provides perspective on the actual outcomes of the experience component, the Clinic, and the regular curriculum. Table 4.2 compares respondent's opinions of the presence of the learning opportunity and their assessment of its quality for the two curricula. The program participants view the experience based curriculum as somewhat richer in developmental opportunities than the regular curriculum (yes-no columns). They viewed the regular curriculum as more focused in the areas of problem-solving skills, technical skills, computation skills, and engineering fundamentals.

Both components or learning systems are complementary and reinforcing. They are complementary because both systems are necessary to achieve what students and faculty view as the most important outcomes. For example, both components do a "very good" job at problem-solving skill development, recognizing that the nature of problems is different in both. However, the experience component is perceived to be substantially better in developing such skills as interpersonal awareness, communication skills and engineering judgment, while engineering fundamentals, technical skills and computational skills receive a better quality assessment in the regular curriculum. The two systems are reinforcing to the extent that learnings from one can be practiced and refined in the other. As an example, one would suspect that the acquisition of engineering fundamentals and technical skills promotes self-confidence, problem-solving ability and good engineering judgement.

Table 4.2 also demonstrates that quality is viewed differently from especially the student and faculty perspectives. Three items - technical skills, computation skills and professional ethics - produced substantially different quality estimates of the experience component. Students thought that the Clinic did a better job of teaching technical skills than did the faculty. However, the faculty perceived the Clinic as substantially better in teaching computation skills and professional ethics than did the students. Interestingly, on the five items exhibiting the greatest differences for the regular curriculum - problem-solving, technical skills, self-confidence building, engineering fundamentals and leadership skills - students give more credit to the regular curriculum than did the faculty.

Program features leading to high quality outcomes were determined by asking students which activities led to their highest quality ratings on the Learning Inventory. Analyzing the Inventory presented in Table 4.2 leadership skills received a 4.5 rating and planning, problem-solving and organizational skills received 4.4 ratings. This is true, in part, because fifth year masters students were included in the sample. Students emphasized the nature of the project and student interaction as those clinic features most responsible for high quality outcomes. The project opened and involve the application of theory. They demand student responsibility and new student learning behavior, team responsibility, successful communication, and human resource management.

The Learning System

The learning system has several key elements which include the nature of the project, the team approach, the assessment process and new teacher/learner interactions. The team approach and the quality of the work are supported in a variety of ways. First, the Clinic has a history, its founders are still at HMC, and the program is institutionalized. Student lore no doubt abounds about the perils, pitfalls and personalities involved in Clinic participation. Over the years some important aids and systems for their use have been developed. For example, a student guidebook was developed through a Sloan Foundation grant. The guidebook brings together informational materials on topics pertinent to the work of the group - communications, group dynamics, the design process, project management and operation, the resources available to students and expectations for performance. Lastly and importantly, junior level engineering students have already participated in a similar team project during their freshman year. This project combines personal interests with work of social value for the academic or surrounding urban community.

Student performance assessment is both summative and formative. Students receive a final grade but they did not indicate that the grade was a "big thing." Only five of the 13 students interviewed were aware of the criteria for grading before beginning their clinic experience. Four of seven faculty members interviewed believed that students were informed of the criteria beforehand. Advisors assign grades taking the recommendations of fifth year project leaders very seriously. They employ both subjective and objective criteria in

TABLE 4.2
LEARNING INVENTORY
HARVEY MUDD COLLEGE

Skill or Characteristic	EXPERIENTIAL PROGRAM						TRADITIONAL PROGRAM					
	Existence of Developmental Opportunity		Average Quality Rating				Existence of Developmental Opportunity		Average Quality Rating			
	Yes	No	All	Stud	Fac	Alum	Yes	No	All	Stud	Fac	Alum
Problem-solving skills	20	1	4.4	4.3	4.3	5.0	20	1	4.0	4.4	3.2	4.5
Interpersonal awareness	20	1	4.1	3.9	4.2	4.0	12	9	2.2	2.3	2.0	2.5
Creative expression	21	0	3.8	3.6	4.0	3.5	16	5	2.4	2.3	2.3	3.5
Communication skills	20	1	4.3	4.2	4.3	4.0	19	2	2.5	2.5	2.3	3.5
Technical skills	20	1	3.5	3.9	3.3	3.0	21	0	4.0	4.1	3.6	4.0
Self-confidence building	21	0	4.2	3.9	4.3	5.0	17	4	2.8	3.0	2.4	3.0
Computation skills	15	6	2.7	2.4	3.0	4.0	20	1	4.5	4.5	4.3	4.5
Engineering fundamentals	17	4	3.2	3.1	3.0	4.0	20	1	4.3	4.5	4.0	4.0
Organizational skills	21	0	4.4	4.6	4.3	4.5	11	10	2.6	2.5	2.3	5.0
Leadership skills	20	1	4.5	4.4	4.5	5.0	6	15	2.0	2.0	1.0	4.0
Planning skills	21	0	4.4	4.5	4.1	5.0	14	7	2.5	2.6	2.2	4.0
Professional ethics	17	4	3.3	2.8	3.8	5.0	9	12	2.7	2.5	2.3	5.0
Engineering judgment	21	0	4.1	3.9	4.1	4.5	18	3	2.9	3.0	2.6	5.0
Quality Scale:			n=21*	n=11	n=7	n=2			n=21*	n=11	n=7	n=2

Excellent = 5; very good = 4; good = 3; fair = 2; poor = 1
*This number includes one administrator not included under faculty.

grading. Criteria include the level of effort and quality of work. The exact criteria, the availability of the criteria to students at the outset and the feedback process vary among the faculty. Students recognize this variability. Some faculty and students share concern over it. Students seek more uniformity and some faculty wonder whether a pass-fail approach might not be better.

Informally students receive and value non-graded critiques of their work from a variety of sources. They receive it from their advisors, from other students and faculty members and from their clients. The students interviewed valued this feedback most from their advisors, next from other students.

Students were asked about their satisfaction with the assessment and evaluation process. Six of thirteen students indicated that they were very satisfied, five that they were somewhat satisfied, no one indicated that he or she was somewhat dissatisfied but two indicated that they were very dissatisfied. The formal and informal assessment processes do not appear particularly well developed, commonly shared, uniformly applied or particularly satisfying to the students and faculty interviewed. Students do, however, report high satisfaction levels for their relationships with their supervisors - 3.5 on a 4.0 scale from "very satisfied" (4.0) to "very dissatisfied" (1.0). Satisfaction results from the high quality contact between the faculty member and students, from their confidence in his competence and from the interest he expresses in their development through the project. Satisfaction with the client relationship is less dramatic - 3.2 on a 4.0 scale. Three students indicated they were somewhat dissatisfied. Dissatisfaction occurs exclusively because of personal relations problems or disappointments not the content of the project.

Teaching/Learning Roles

The very nature of the Clinic promotes new learning roles for students and new teaching roles for faculty. Students in teams are relatively autonomous learners, responsible in a new way for the results of their learning and the products of the effort. They are challenged to apply theory to "real world" not "book" problems. They conceive of Harvey Mudd with its faculty, labs, shops, support personnel and students as resources to be identified and applied to their project. Their motivation to perform seems more complex in the Clinic than in the regular curriculum. They are intrinsically and extrinsically rewarded through developing new and sometimes untested skills.

Clinic participation forges a new faculty role as well. Generally, faculty members view their role as an academic resource but also as someone responsible for advising, directing and evaluating. This new role differs from the traditional role. To gain some sense of the differences, faculty members were asked to fill out a program inventory. The data from the inventory are presented in Table 4.3. The new role is perceived as a bit more demanding.

Faculty comments suggest that it is more ad hoc. Students seek faculty members on an "as needed" basis.

Supplemental Outcomes

The Clinic's educational impact on students and faculty is broad. Generally, it has benefited the students, faculty, clients, and institution in many, many ways. Faculty members experienced academic or intellectual growth through clinic participation. Apparently the challenge of new "real world" problems combined with a new teaching role was very stimulating. Some faculty members published and consulted because of their projects. Finally, two professors mentioned that they felt better professionally, as educators, because they saw students benefit in new ways from the clinic experience.

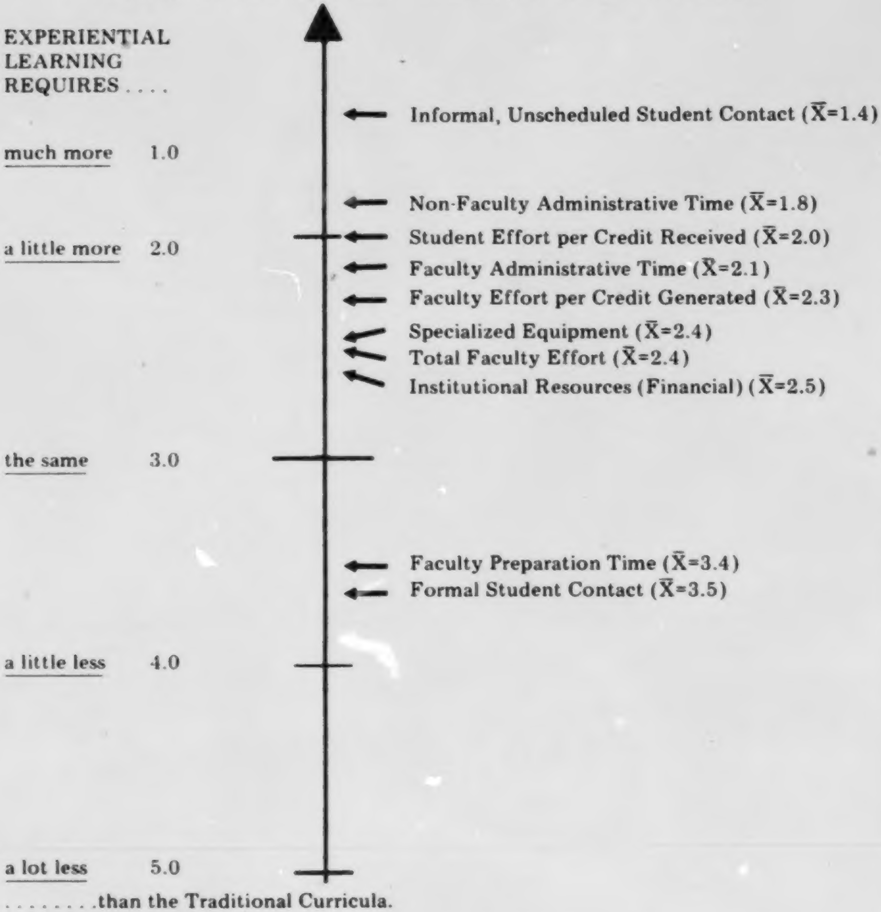
Clients benefit from the Clinic because their project work is accomplished in a processional manner, they have an opportunity to recruit the students for employment and they gained new knowledge because of the fresh approaches students take in solving the problems. The Clinic experience impacts on student's attitudes as well as their knowledge. Students unanimously affirmed that they had a more realistic impression of engineering because of clinic involvement. Eight of thirteen students reported more positive impressions, three said their impressions were more negative. Students were asked how the Clinic affected their commitment to an engineering career. Six said they were more committed. Five said that the Clinic hadn's really affected what was already a firm commitment. One didn't know how it had affected his commitment and for another commitment to an engineering career decreased.

For Harvey Mudd as an institution the Clinic provides visibility, positive relationships with practitioner and revenue from a standard fee charged to the client. In broad perspective, the clinic provides a potent learning experience for students and faculty consistent with Harvey Mudd's educational goals of combining engineering practice with human concerns and sensitivities.

Students and faculty do see some disadvantages in clinic participation and identified some important problems inherent in the clinic participation. Harvey Mudd students are very bright and many attend graduate school. Two respondents indicated that for students bound for a purely academic career, the Clinic was not germaine. Because the Clinic is a tremendously time and energy consuming enterprise, some students felt it was robbing them of energy best spent on developing more technical expertise. Some faculty members were also struggling with the appropriate balance between design activities such as the Clinic and course activities emphasizing engineering fundamentals and technical expertise. These balances may be a special point of concern in a program dedicated to substantial breadth through non-engineering requirements.

TABLE 4.3

PROGRAM INVENTORY* HARVEY MUDD COLLEGE



*The program inventory was developed to diagnose, however impressionistically, important differences between the experiential and traditional curricula. Ten key items on which to explore differences were selected. They appear on the right hand side of the table. Respondents scaled the items from 1-5 depending on how much more of the item was demanded by experiential education in comparison to the traditional classroom setting. The scale is represented on the left hand side of the table.

Summary

Several features of the Clinic are important to reiterate in summary. It is a relatively mature program, begun in the early sixties, which has capitalized on its experience and developed various supports to accomplish its goals, e.g., the Guidebook, feedback forms and numerous reading materials. The learning environment for students is defined by: 1) the project - an open-ended, real world, complex problem demanding the application theory and technical expertise; 2) the student-led, team approach that takes many students interdependently from project creation to report completion; 3) the personal and physical resources of Harvey Mudd College; and 4) the contractural, funded, relationship between the client and HMC.

Program participants identified a wide variety of Clinic strengths. The "real world" nature of the experience was mentioned most often as a strength. "Real world" means different things to different people but implied are: 1) a problem/orientation as opposed to a disciplinary orientation; 2) the openended complexity of the situation; 3) the responsibility and potential impact of solving the problem. Mentioned almost as frequently were the rich interpersonal demands and relationships fostered by the student-lead team approach. Students were challenged to grow in new ways, to lead, to cooperate, to manage and to establish new kinds of relationships with their professors.

Individual skill development and closely related to it, personal development were often reported as important strengths. Participants viewed the Clinic as fostering broad development of professional and general skills from design competence to leadership or management ability. Also it stimulated personal development in such areas as communication, judgment and cooperation. Very importantly it breeds self-confidence both professionally and personally.

In addition to asking participants to identify strengths, weaknesses were also solicited. The primary concern dealt with project selection. Projects are a key element in the Clinic and concern is understandable. They must be valuable learning vehicles and they must fit HMC faculty resources and student need. Once these criteria have been met, a complicated matching process must be well-managed. Students must match their substantive interests and technical backgrounds with available projects and their personal preferences for other students and faculty interested in or involved with the same projects. Concern over projects suggests that project selection and the matching process doesn't always work out ideally. Some matching problems seem insolvable because of the many variables in one particular year, but others seem solvable if adequate project variety is maintained.

Time pressures were also noted as a weakness. They involved matching the "industrial calendar" and the "academic calendar." They also involved the pressure on one hand to take technical electives versus the time required for the Clinic. Also, "flounder" time was mentioned as a weakness. This involves "wheel spinning" time during the project's start-up when students are new to the whole process. The difficult pedagogical is, no doubt, to balance "floundering" time which promotes good learning against "floundering" time which wastes effort and resources.

Where do program participants see a mature program like the Clinic headed? A thread of student opinion focused on improving the project matching process. Some suggested that the team leadership role be spread among more students. This desire and other comments suggest that the team leader role is an especially potent responsibility fostering much learning. Faculty and administrators saw several future challenges. Keeping the program vital was one. Vitality flows from attracting good projects, keeping faculty interest keen and student/faculty interaction personal plus fine-tuning the activities of the Clinic. Fine-tuning might involve better utilization of support courses such as those in the engineering sciences, writing and speaking.

Harvey Mudd educators pioneered a "real world" approach to educating engineers through the Clinic. Students learn new and important skills. The Clinic fosters realism and commitment. Faculty members benefit, clients benefit and Harvey Mudd as an institution gains visability and support. While not without some weaknesses and apparently inherent problems, the Clinic admirably exemplifies its approach to engineering education.

5

The Kansas State University ME Design Laboratory

As part of the senior year curriculum in Mechanical Engineering, all majors at Kansas State University are required to participate in an M. E. Design Laboratory. This industrially-based, experiential aspect of the curriculum is a two-credit, capstone laboratory course for M. E. Majors. It is intended to serve as a transitional vehicle which introduces students to the types of problems they will encounter "on the job" and affords them an opportunity to apply a cross section of their course work to real world problems.

The students, working in three to four person teams, solve actual engineering problems that are submitted by industrial clients. These industrial firms represent a diverse geographical group from Texas to Indiana and offer a broad cross-section of projects (e.g., from pipelines to grain dryers). In any one semester 6-8 teams of senior M. E. majors are working toward the presentation of both a written and an oral report to the client on a proposed solution.

History

In the Fall of 1966 the Mechanical Engineering Department introduced the senior M. E. Design Lab Project as a required part of the curriculum. Since 1970, this two-credit project experience has been a course designed to ease the transition between the academic world of the classroom and the applications-oriented working world.

Two contextual characteristics are important and distinguish this experiential curriculum component from other programs reviewed in this monograph. First, the M. E. Design Lab is a two credit hour course and thus represents only a small portion of the total curriculum. Second, this course has been in existence in essentially the same form for nine consecutive years; thus it is institutionalized and not "greeted" by students with the same enthusiasm that a much bally-hooed innovation might be.

Program Description

Within any one semester, the process of organizing the M. E. Design Lab begins when the department receives pre-enrollment statistics. From these figures the number of projects needed for the upcoming course is determined based on three or four person teams and projects are solicited from industry. KSU has prepared a "participation agreement" which each client must sign. This brief two-page document formalizes the obligations of all parties in a contractual form.

Brief background statements on each project are prepared by the supervising professor and distributed to students. From this information the students preferentially rank each project. Using these preferences as input, professors then assign students to a project, thereby creating three to four person teams with one professor supervising a maximum of four projects. With the exception of two initial lectures on problem-solving, the remainder of the Lab course is given over exclusively to the solutions of their engineering design problem. After projects have been assigned a representative of the client firm will usually travel to the school to make a detail presentation to the design team, although some firms prefer that the students visit the plant site.

Although the format varies across faculty, students meet with their supervising professor on a weekly basis. At this time the week's progress is reviewed, and next week's goals are agreed upon. The students have the freedom to place a collect telephone call to the client once a week to gather information and get important questions answered. Twice during the term students are required to send written progress reports to the client and make oral presentations to their classmates. Feedback from the client is encouraged, but it is received infrequently.

All of the work in this two-credit laboratory is focused on the ultimate production of a written report which is bound into a highly professional document and presented to the client. A project team accompanied by its supervising professor travels to the client's home base to make an oral presentation and defend the proposed solution. This visit serves not only to present and discuss the written report but also gives the students an opportunity to tour the plant facilities and become more familiar with the client's environment. The written and oral reports form the basis for evaluating performance in the course. From this work and the interaction throughout the semester the professor assigns each student a letter grade.

Program Objectives

The rationale in establishing the KSU Design Lab was to offer the students an opportunity to gain first-hand experience in solving real-world engineering problems. Both faculty members and students overwhelmingly indicate that the primary purpose was to provide experience in solving a real world problem. Similarly the administrators comment that the primary thrust behind this program was to provide an educational benefit for the student. These responses seem to be consistent with the original intent of establishing the program.

It is interesting to contrast these purposes and expectations with the benefits which the clients hope to gain from being involved. All three of the clients interviewed indicated that this program is a direct benefit to their own operation in recruiting new employees. Through the Design Lab, students were exposed to the client company and its way of operation. Thus recruiting was easier and a natural entre was created. In addition, some project solutions have been implemented by the clients and two patents have resulted. Finally, clients recognize the educational benefits which these projects provide students, and these firms view this as an opportunity to assist the educational community as responsible corporate citizens.

To focus these broad objectives, the respondents in our survey scaled the relative importance of a possible set of student learning outcomes. These data are presented in Table 5.1. There is general agreement across all three groups on the critical importance of gaining Problem-Solving Skills, Planning Skills, and Engineering Judgment. In contrast, Computational Skills item received a more diverse mix of ratings. As the table indicates both students and alumni on the average rated this as the least important skill whereas faculty on the average rated it in the middle relative to the other skills listed.

The greatest intergroup difference appears in Professional Ethics and Leadership Skills. Faculty and alumni rated Professional Ethics as one of the most important qualities for a graduate to possess (the third highest faculty rating and the second highest alumni rating), whereas students rated it as one of the least important skills with an average rating of 2.8. Leadership Skills also received an interesting mix of ratings. Of the students interviewed 60 percent assigned this skill the highest importance rating but only one of six faculty gave it a comparable rating. Although this skill ranked second highest on the average for students, it ranked the lowest for faculty members.

There is general agreement on Problem-Solving, Planning and Engineering Judgment as important skills. The difference of opinion on Engineering Fundamentals, Computational Skills, Professional Ethics and Leadership Skills should be kept in mind as particular aspects of the ME curriculum are discussed.

Program Outcome

A comparison of the learning outcomes reported by students, faculty and alumni between the experiential activity and traditional classroom work is displayed in Table 5.2. The responses indicate that almost unanimously faculty felt that students had some opportunity to develop all of these skills in the ME lab.

Students, although not in as high agreement, generally concurred that the opportunity was available in the Design Lab. Notable exceptions are Professional Ethics and Computational Skills in which nearly half of the respondents indicated that opportunities were not provided to develop these skills.

A comparison of the quality ratings between students, faculty, and alumni shows all three groups agree that the opportunities for developing Planning and Leadership skills are very good with the lowest average score being a positive 3.6 assigned by the students. Students report that they develop their Leadership Skills by interacting with other students and improve their Planning Skills by learning to cope with the unstructured nature of a project.

This consistent feeling between faculty and students regarding the Planning and Leadership opportunities stands in contrast to some of the other skills. Quality ratings for Interpersonal, Computational, and Organizational skills result in some interesting discrepancies. The largest difference appears in the quality rating of Interpersonal skills, with seven of the nine students rating it a "fair" (=2) or "good" (=3). In direct contrast, all six faculty indicate the opportunity to develop Interpersonal skills is either "very good" (=4) or "excellent" (=5). A similar pattern exists for both Computational skills and Organizational skills with 70 percent of the students assigning a quality rating which is lower than the lowest faculty member's rating. For every skill in the inventory, the students assign a lower average quality rating do faculty members. Alumni, on the other hand, rate Problem-Solving, Creative Expression, Organizational and Planning skills higher on the average than do the faculty.

In contrast to the quality ratings of the ME Design Lab, the ratings for the traditional classroom experience were consistent between students, faculty, and alumni. This consistency in perspective holds-up across all skills and stands in marked contrast to the differences in the ratings for the Design course. In the traditional program all groups recognize the high quality opportunities to develop Problem-Solving, Computation, Engineering Fundamentals and Technical Skills. These groups also agree that the typical course does not present a high quality experience for developing Professional Ethics or Communication Skills.

Whereas students always rated their experiences lower than faculty did, for the Design Lab, there is no such pattern for the traditional curriculum. For some skills (e.g., Problem-Solving, Judgment) faculty perceive a higher quality experience than do students; for others (e.g., Leadership, Interpersonal Awareness) students perceive a higher quality than do the faculty. Thus the pattern of students more critically evaluating course experiences which is evident for the Design Lab is not characteristic of the students' rating of the "regular curriculum."

In summary, the basic skills of Engineering Fundamentals, Computational Skills, and Problem-Solving Skills are being provided by the regular academic classroom. Everyone also agrees on their importance. Other important characteristics such as Planning Skills, Engineering Judgment and Leadership Skills are being developed in the ME Design Lab. Thus these two quite distinct aspects of the curriculum are complementary, and together they meet the perceived needs of engineering students.

Table 5.1
KANSAS STATE UNIVERSITY
Importance Of Attaining These Skills
Constituency Group Average

	All	Student	Faculty	Alumni
Problem-solving skills.	3.7	3.8	3.5	3.8
Interpersonal awareness.	3.1	3.0	3.3	3.0
Creative expression.	3.2	3.2	2.8	3.5
Communication skills.	3.4	3.3	3.3	3.8
Technical skills.	3.3	3.2	3.2	3.5
Self-confidence building.	3.1	2.9	3.2	3.5
Computation skills.	2.9	2.6	3.3	2.8
Engineering fundamentals. . .	3.6	3.4	3.8	3.8
Organizational skills.	3.3	3.2	3.3	3.5
Leadership skills.	3.3	3.6	2.8	3.3
Planning skills.	3.6	3.5	3.5	3.8
Professional ethics.	3.2	2.8	3.5	3.8
Engineering judgment.	3.7	3.5	3.8	4.0
Importance Scale:	n = 20	n = 10	n = 6	n = 4

Crucially important = 4; very important = 3; somewhat important = 2; not too important = 1.

The Learning System

There are four important aspects of the learning system: 1) choice of clients; 2) student selection of projects; 3) student-faculty-client interaction; and 4) the assessment of student performance. In the Kansas State program initial contact with clients usually occurs as a result of faculty initiative. Faculty look for projects which require the direct application of engineering theory. A good mix of products is sought and care is taken not to overburden a client with too many projects. One project per year per client is the goal.

As indicated earlier, design teams are created by the faculty assigning students to each project. Some students indicate a dissatisfaction with this procedure citing both the mix of projects from which they have to choose and the uninteresting nature of some problems. Dissatisfied students comment that they would like problems that are more in keeping with their professional interests, yet faculty point out that this represents what happens in industry.

Students indicate a high level of satisfaction in their interaction with faculty ($X = 3.6$ on a 4 point scale) yet expressed some frustration and disappointment in their relationships with their client. Of the 15 alumni and students interviewed, 14 indicate that they are only "somewhat satisfied" or even "somewhat dissatisfied;" only one student responded "very satisfied." Clients are frequently difficult to contact and they do not promptly respond to students' request for information. This frustrates the project team which relies on prompt turnaround to stay on its work schedule.

The Kansas State faculty feel a sense of responsibility to the client and view themselves as a "quality control mechanism" to guarantee that the clients receive good work. Each of the clients interviewed indicated a high degree of satisfaction in their communication with the Mechanical department.

In summary, the communication between students and faculty seems extremely good as does the interaction between the ME Department and the clients. Communication between project teams and the client is problematic and could be improved to benefit the educational experiences of the students.

The grading of team projects presents many unique problems. The interdependency within the team effort makes it difficult to evaluate individuals. Similarly, the criteria for evaluating a written report and oral presentation by a team are far different than those employed in the traditional academic classroom. Faculty readily admit that the criteria they employ for grading are subjective. Although faculty indicate that students are informed of these subjective criteria, students strongly suggest that they are not aware of the criteria. When asked how satisfied they are with the formal evaluation process 60 percent of the students responded "somewhat." To support this reaction as significant number of students also mentioned "grading" as a weakness of the ME Design Lab.

TABLE 5.2
LEARNING INVENTORY – KANSAS STATE UNIVERSITY

Skill or Characteristic	Experiential Program						Traditional Program					
	Existence of Developmental Opportunity		Average Quality Rating				Existence of Developmental Opportunity		Average Quality Rating			
	Yes	No	All	Stud	Fac	Alum	Yes	No	All	Stud	Fac	Alum
Problem-solving skills	20	1	3.7	3.2	3.7	4.4	20	0	4.2	3.8	4.5	4.5
Interpersonal awareness	20	1	3.6	2.9	4.3	3.8	16	4	3.1	3.3	2.8	3.0
Creative expression	18	3	4.1	3.7	4.2	4.4	18	2	2.7	2.3	3.0	3.3
Communication skills	21	0	3.8	3.3	4.2	4.4	19	1	2.5	2.4	2.2	3.7
Technical skills	18	3	2.9	2.4	3.4	3.4	20	0	4.1	4.1	4.3	3.8
Self-confidence building	19	2	3.7	3.0	4.3	4.2	20	0	3.0	2.9	3.0	3.3
Computation skills	14	6	2.5	2.4	2.7	2.3	19	0	4.2	4.1	4.0	4.8
Engineering fundamentals	18	3	2.8	2.6	3.0	3.0	20	0	4.4	4.2	4.3	4.8
Organizational skills	21	0	3.9	3.3	4.5	4.4	19	1	3.2	3.3	2.8	3.5
Leadership skills	20	1	3.8	3.6	4.0	3.8	17	3	2.8	3.0	2.4	2.7
Planning skills	20	0	4.1	3.8	4.2	4.4	19	1	3.0	2.9	2.8	3.5
Professional ethics	15	6	3.3	3.0	3.2	3.8	14	6	2.6	2.3	2.4	3.3
Engineering judgment	21	0	4.0	3.5	4.5	4.6	20	0	3.3	3.1	3.5	3.5
			n=21	n=10	n=6	n=5			n=21	n=10	n=6	n=4

Quality Scale:
Excellent = 5; very good = 4; good = 3; fair = 2; poor = 1.

Teaching/Learning Roles

The team approach demands a set of student skills which are ordinarily not emphasized in the regular classroom setting. "Class" work now becomes a logistical problem of coordinating the schedules of four persons. When group leadership is required, someone must take the initiative and step forward. The group must also deal with the student who is not contributing a fair share to the workload. All of these situations accentuate a different set of skills and cast the students into a different role than in the traditional classroom format.

Faculty Role

An experiential education program places the faculty member in a totally different environment. The data reported in Table 5.3 compares faculty activity for the Design Lab to the "traditional classroom model." There seems to be little doubt that the faculty feels that both students and faculty doubt that the faculty feels that both students and faculty give more effort per credit generated for the two-credit Design Lab. Faculty members generally feel that they have more contact with students both formally and informally. Some faculty set aside a three hour "class" period during which students may work on their projects and receive some input from faculty members. Other faculty let students work within their own schedule and then meet separately with each group once a week to review progress. This difference in format may explain the wide divergence of opinion regarding the amount of formal student contact in the Design Lab.

Faculty members indicate a wide divergence of opinion on the relative amount of preparation time required for such a course. Two faculty indicate that the Design Lab requires "much more" preparation time whereas two others indicate it requires "a little less." Further analysis indicates that the faculty **most frequently involved** in teaching the Design Lab were the ones who indicate that preparation time is about **the same or less** for the experiential course. In contrast the faculty who had **not** taught this course perceived that it required more preparation time than the traditional class.

Because of the radical departure from the usual course format, the ME Design Lab requires a different mix of faculty skills. Faculty and administrators emphasized the importance of having industrial experience and also expressed a desire for having increased technical skills. The wide range of projects which faculty encounter in these client-based requires a broad base of technical expertise. As one faculty said, "You must be willing to get involved in an area that you know little about." Thus faculty must be willing to say, "I don't know;" and then dig in with the student to find an answer.

Because of the close working relationship with students, faculty also indicate a desire for more highly developed interpersonal skills. This is supported by their own admission that they have not been "trained" to teach in this type of environment. The experiential, problem-oriented format requires a different mix of technical and interpersonal skills. Faculty members appreciate the contribution this lab makes to their own professional development, particularly since they personally get involved in many different types of projects. They also recognize that a special "fit" between a faculty member's personal teaching style and this experiential course is required.

Supplemental Outcomes

Faculty, clients and students receive different benefits from being involved with the ME Design Lab. Faculty members report that the variety of projects and the contact with clients provides them with personal and professional growth. Clients of the Kansas State program view the Design Lab as a good vehicle for recruiting purposes. These firms also indicate that the project solutions contribute to the overall knowledge of their firm through both the written reports and oral presentations. In addition, clients indicated that by circulating these to project engineers for their general reading, their own professional development was enhanced.

The students and alumni provided a somewhat mixed impression of the program, reporting a higher degree of satisfaction with their regular academic program than they did with the Design Lab.

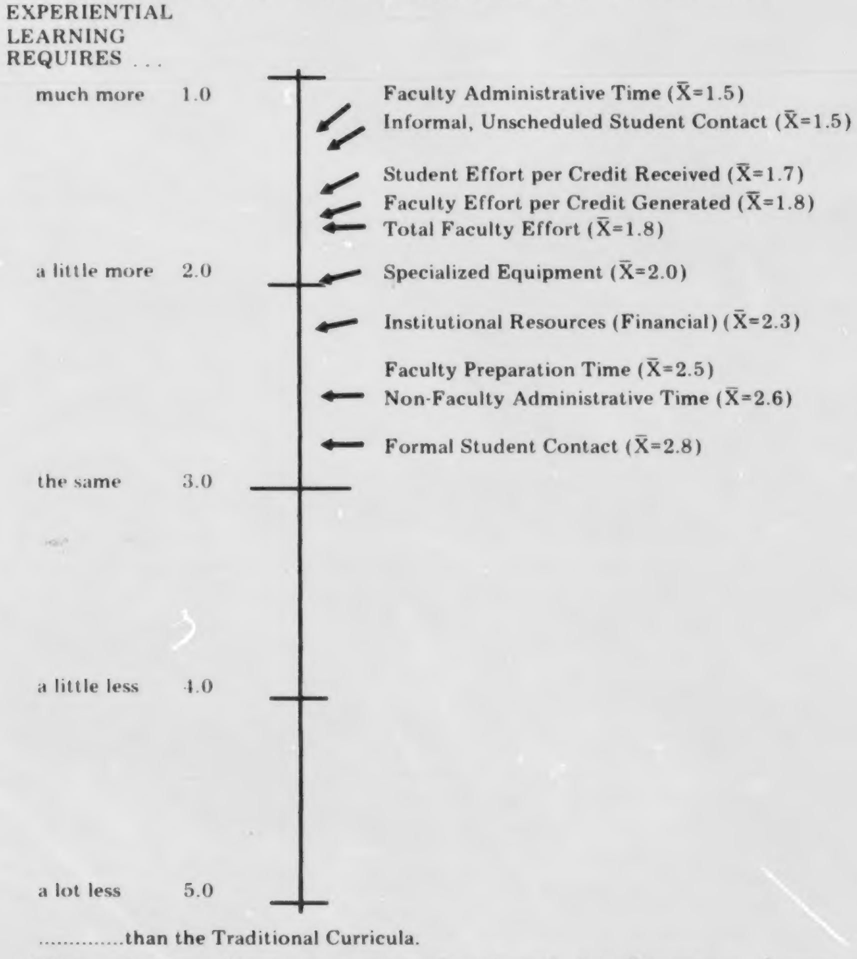
The summary in Table 5.4 demonstrates that the differences in satisfaction are not great, yet it is also fair to say that the students do not regard this course as an exceptional experience which produces a high level of satisfaction. In talking with students, it is obvious that each has a very different experience; and their overall level of satisfaction is in large part determined by the specific project they are given. Also, because this is a two credit course these seniors find little reason for devoting a great deal of effort and enthusiasm to a project if it is uninteresting to them and not in keeping with their specific area of professional interest.

The students report relatively little change in their commitment to engineering or their impressions of engineers as a result of this course. Twelve students reported no change in their commitment to engineering and thirteen of the fifteen interviewed reported no change in their impressions of engineers and engineering. Many of these students off-handedly remarked that they had already formed a detailed impression of engineering through summer jobs or plant visits, and by their senior year the Design Lab had little impact on this impression.

Summary

The Design Lab at Kansas State University is a well established, effectively run, experiential component of the Mechanical Engineering curriculum. The fact that the project is in its ninth year and is favorably received by faculty, students, and industrial clients is a testimony to its success. The Lab was

TABLE 5.3
PROGRAM INVENTORY* KANSAS STATE UNIVERSITY



***The program inventory was developed to diagnose, however impressionistically, important differences between the experiential and traditional curricula. Ten key items on which to explore differences were selected. They appear on the right hand side of the table. Respondents scaled the items from 1-5 depending on how much more of the item was demanded by experiential education in comparison to the traditional classroom setting. The scale is represented on the left hand side of the table.**

established to offer real world experience to the students and give them some background in a design problem. The learnings and the strengths of the program which both students and faculty report indicate that the program is accomplishing its intended purposes. Most importantly, this two-hour course adds an important complementary set of experiences to the ME major. The skills which students develop such as Planning, Leadership, Creative - Expression, and Engineering Judgment are regarded as integral parts of a student's overall growth and development. Thus, the Design Lab is a strong complement to the traditional curriculum.

Although this program is well established and functioning smoothly, the program appears to have four basic opportunities for improvement. First, students and faculty alike comment on the need for a good mix of projects. Faculty members view this as an administrative challenge to their continued offering of this course. Students indicate that if a greater variety of projects could be offered from which they could select, this would significantly improve the program. Secondly, both students and faculty recognize the difficulty in evaluating persons individually when everyone contributes to the single product of the project. Thirdly, the student-client interface presents a unique challenge. Students desire increased contact with their clients. Through this they would learn more about the firm but even more importantly students would be able to place the project in a larger context and more easily get the necessary background information required for project completion. Finally, this project by its placement in the curriculum (i.e., senior year, one semester) is not reaping the educational benefits which it potentially might. Students see the projects as standing somewhat in isolation to their education. Because of the modest amount of contact with the client and the semester deadline students feel that they are unable to follow through on their projects. In other words, they lack a sense of closure. Beyond this, non-seniors in the ME Department get little benefit from the tremendous learnings of their student colleagues.

None of this is to say that the ME Design Lab is a failure. It is a carefully designed, well-run integral part of the curriculum. This example of experiential education can no longer be termed an innovation, for the Kansas State faculty has institutionalized this import aspect of engineering education and it is functioning smoothly. With a minimal departure from the time-tested academic curriculum the Design Lab provides an important experiential component for the mechanical engineering major. This model represents a viable alternative for those considering the establishment of an experiential component within the existing curricular framework.

TABLE 5.4

Satisfaction Levels of Students and Alumni

	Lab	Academic Program
Very Satisfied	7	9
Somewhat Satisfied	6	5
Somewhat Dissatisfied	1	1
Very Dissatisfied	1	0
Total Respondents	15	15

6

The Worcester Polytechnic Institute Plan Program

In 1971 Worcester Polytechnic Institute embarked upon a most ambitious curricular plan which resulted in the total revamping of their learning environment. The WPI PLAN, as it has come to be known, is an attempt to provide engineering students with an education that is in keeping with the contemporary world. The PLAN was designed specifically to provide "a new and comprehensively different educational program, responsive to the needs of individual students and society while encouraging sensitivity to the ideas and values of civilization."

History

The actual planning for this new curriculum began in the early '60's with a recognized need for students to gain offcampus experiences. In the summer of 1968, careful work was initiated by a faculty committee to develop goals for the new curriculum, and in December of 1969 a goals statement was unanimously adopted by the WPI faculty. From this goals statement flowed the design of the WPI PLAN.

The PLAN emphasizes competencies, individual freedom within a student's curriculum, self-initiated investigation, and new instructional methods which join the students and faculty in a learning partnership. This has resulted in a restructuring of degree requirements, and all students must demonstrate their qualifications for graduation through successful completion of four major activities: 1) a competency evaluation in the major field of study; 2) the major qualifying project (MQP); 3) the interactive qualifying project (IQP); and 4) a sufficiency in a minor area.

Program Description

The two qualifying projects, the MQP and the IQP, represent the experiential dimension of the WPI PLAN. The Interactive Qualifying Project (IQP) focuses on the interactions of technology with society in human values. An IQP may range from studying the impact of an educational satellite to teaching guitar lessons to a juvenile delinquent. These projects are often times expensive and allow these future engineers to gain first-hand experience with a set of societal issues they might not normally encounter. The Major Qualifying Project (MQP) integrates formal academic studies in one's major field via an in-depth research project. Although each of these graduation requirements are project-oriented, it is obvious that their purposes are quite distinct.

With the introduction of the PLAN, a unique academic calendar was instituted consisting of four, seven-week terms with a two-week intercession between the second and third terms and an optional summer term. For any single term students register for a total of one unit of activity with a traditional three-credit semester course translating into one-third of a unit. Both the IQP and the MQP are designed to each require one unit of activity for a seven week term. Students may register exclusively for project work and thus spend fulltime for seven weeks on their project. Many students, however, opt for spreading a project over a number of terms and will register for fractional units of project activity, independent study and classes totaling one unit of activity per term. WPI alumni thus graduate with at least two units or project activity, two units in humanities, and a total of approximately sixteen units.

Project activity for both the IQP and the MQP takes place in a variety of formats. More often than not, projects are completed in two- or three-person student teams. Interactions with clients range from no involvement with a client to literally changing residence for a seven-week term and working as a full time employee. Client involvement can be broadly grouped into three alternatives. First, students may literally set out to accomplish the objectives which a client has outlined. In this case, students will be working much like an employee of the firm. Approximately 200 projects (24%) are this type. Second, students may work on an offcampus project which has student or faculty designed objectives. This may involve some interaction with a set of "clients" but the focus of responsibility resides on campus. Approximately 100 projects (13%) are this type. Third, projects may involve no off-campus experience. Such projects may be a laboratory experiment or a library research project. Approximately 500 (63%) of the student projects are of this variety.

To expand the number of off-campus projects, WPI is establishing a set of project centers. One of the most exciting is the Washington, D. C. Project Center. This "branch campus" of WPI takes full advantage of the nation's capital and its resources to generate stimulating project activity. Other centers have been established at a nearby hospital and a local manufacturing firm.

These WPI Centers will facilitate project coordination and build on project experience.

To assist students in designing and planning their projects, two voluntary "proposal courses" are offered, one for the IQP and one for the MQP. The objectives of these courses are to assist the students in generating a detailed research proposal for their own IQP and MQP.

Upon completion of the projects, a detailed report is written, much like a technical paper or engineer's report.

Students may complete the MQP and IQP anytime in their academic career and in any sequence. In actuality, students are encourage to complete their IQP-the societal based problem-during their sophomore or junior year. The MQP normally requires a thorough grounding in the major field of study and therefore is usually completed in the final term of the junior year or in the senior year. On occasion students will get involved in a research project in their major field during their sophomore or junior years. This often times results in early completion of their MQP. Projects may receive one of three grades: acceptable with distinction; acceptable; or not acceptable. This grading system is also used for course work at WPI with the exception that no record is kept for work that is unacceptable.

Program Objectives

The experiential component at WPI, the IQP and the MQP, was established with two purposes in mind. First, these projects afford students with an opportunity to use their newly acquired knowledge. Without a project component, there is a counterproductive time lag between the acquisition of knowledge and the utilization of this knowledge in behavioral terms. Second, the experience component was established to meet the needs of WPI's many applications-oriented students who wanted to "get their hands dirty."

Faculty view the MQP and IQP as enhancing the general education of students and see it providing valuable real world experience for WPI graduates. Administrators view this program as responding both to needs of students and the needs of the faculty, whereas students view the experience-based program as a chance for both professional and personal growth. In contrast, the clients hope to gain benefits for their own firm by involvement with the WPI PLAN.

To focus these goals, program participants rated the importance of various student learning outcomes. The results of this scaling, shown in Table 6.1, demonstrates that all these outcomes are viewed as important. The students emphasized skills such as Problem-Solving, Communication, Interpersonal Awareness, Engineering Judgment, and Planning. Faculty and administrators rate Engineering Fundamentals, Problem-Solving and Engineering Judgment as crucially important. Thus, in contrast to students, the faculty and administration emphasizes the more technical aspects of engineering education.

The largest difference between constituency groups occurs in the ratings for Engineering Fundmentals. Relatively, faculty assign to this skill the highest degree of importance, administrators rate it second, and students rate it near the bottom.

Across all groups there is general agreement on the importance of Problem-Solving Skills, Engineering Judgment, and Communication Skills. Within each group, however, there is a wide divergence of opinion regarding the importance of each skill. In other words, the faculty and students disagree among themselves on the importance of various skills. Nevertheless, the overall consistency represents a healthy picture and indicates that students, administrators and faculty are working towards the same ends.

Program Outcome

Given the relative importance of learning outcomes, the data in Table 6.2 compares the outcomes of the traditional curriculum to the experiential program. For the experiential program the faculty and administrators almost unanimously indicate that the opportunity is available to develop each one of these skills. Students are more mixed in their responses with half indicating that the opportunity to develop Engineering Fundamentals does not exist in either the MQP or the IQP. The "no" votes may reflect the broad nature of the IQP, for the projects are very diverse, and students are involved in a range of different activities.

For the experiential curriculum the quality ratings for the opportunity to develop these skills are very high and extremely consistent among faculty, students and administrators. Seven different skills including Problem-Solving, Interpersonal Awareness, Communication, Self-Confidence, Organization Leadership and Planning all receive average quality ratings of "very good" (4.0) or higher. These respondents are obviously very positive about the quality of education students receive from the IQP and MQP. Individual student and Faculty responses do differ significantly, yet there are no sharp group differences. Most importantly, there is a consistent pattern of extremely high responses across a large number of skills indicating that the IQP and MQP afford an excellent opportunity to develop important engineering skills.

An evaluation of the traditional portion of the curriculum is presented on the right-hand side of Table 6.2. It should be noted that the non-experiential dimension of the WPI curriculum is distinctly different from the typical academic classroom. Students may register for individual modules in a particular field and study independently at their own pace. Therefore, these ratings of the "traditional" are a reaction to not only classroom work but to individualized self-paced study.

Table 6.1
WORCESTER POLYTECHNIC INSTITUTE
Importance Of Attaining These Skills
Constituency Group Average

	All	Student	Faculty	Admn.
Problem-solving skills.	3.7	3.6	3.6	4.0
Interpersonal awareness.	3.3	3.3	3.4	3.3
Creative expression.	3.1	3.1	3.0	3.3
Communication skills.	3.5	3.4	3.4	3.8
Technical skills.	3.2	3.1	3.6	3.0
Self-confidence building. . . .	3.0	2.9	3.0	3.0
Computation skills.	3.0	2.7	3.2	3.5
Engineering fundamentals. . .	3.4	2.9	4.0	3.8
Organizational skills.	3.0	3.1	2.6	3.0
Leadership skills.	2.6	2.5	2.8	2.8
Planning skills.	3.1	3.2	3.0	3.3
Professional ethics.	3.1	2.8	3.4	3.8
Engineering judgment.	3.4	3.2	3.6	3.8
	n = 21	n = 12	n = 5	n = 4

Importance scale:

Crucially important = 4; very important = 3; somewhat important = 2; not too important = 1.

A substantial number of respondents indicate that the opportunity does **not** exist within the traditional curriculum to develop particular skills. Over half the responses for Leadership and approximately 40% of the responses for Interpersonal Awareness claim that the opportunity does **not** exist to develop these skills within the traditional curriculum. In addition, Creative Expression, Communication Skills, Professional Ethics and Planning also received a significant number of no votes from at least one of the three groups. One-third of the students (4 of 12) indicate there is not an opportunity to build Self-Confidence within the traditional program although the faculty and administrators unanimously feel there is such an opportunity. Forty-two percent of the students (5 of 12) also feel there is not an opportunity to develop Professional Ethics in the traditional curriculum. Again, the faculty and administration seem quite convinced that there is. With only two exceptions, both students and administrators perceive that there **is** an opportunity to develop Organizational Skills within the traditional program in contrast to four of the five faculty interviewed who feel there is **not**. Thus, a significant portion of the respondents indicate that the traditional program does **not** provide an opportunity to develop Leadership Skills, Interpersonal Awareness, and Creative Expression.

The quality ratings for the traditional program, much like the experiential curriculum, produce a highly consistent pattern among students, faculty and administrators. Each of these groups gives the highest quality rating to the same four skills: Engineering Fundamentals, Computation Skills, Technical Skills and Problem-Solving Skills. Engineering Fundamentals received the highest quality ratings from all three constituency groups, while Computational Skills and Technical Skills received either the second or third highest rating by each group. Quality ratings for Interpersonal Awareness, Planning, Organization and Communication are each below the midpoint on this five point scale. Thus, there is unanimity of opinion regarding the traditional program in both its high quality and lower quality opportunities. The more technical aspects of engineering education such as Engineering Fundamentals, Technical Skills and Computational Skills receive very high marks in the traditional program, while the remainder of the skills on this inventory receive significantly lower ratings.

Comparing Table 6.1 to Table 6.2, self-perceived learning outcomes can be contrasted with the skills and characteristics people feel are most important. Table 6.1 shows there is general agreement on the importance of mastering Problem-Solving Skills and Table 6.2 supports the high quality of the opportunities to develop these skills in both the experiential and traditional segments of the curriculum.

Engineering Judgment is also rated as extremely important by all three groups. Faculty and administrators assign a very high rating to the opportunity

TABLE 6.2
LEARNING INVENTORY – WORCESTER POLYTECHNIC INSTITUTE

Skill or Characteristics	Experiential Program						Traditional Program					
	Existence of Developmental Opportunity		Average Quality Rating				Existence of Developmental Opportunity		Average Quality Rating			
	Yes	No	All	Stud	Fac	Adm.	Yes	No	All	Stud	Fac	Adm.
Problem-solving skills . . .	20	1	4.4	4.4	4.0	5.0	21	0	3.6	3.8	3.6	3.0
Interpersonal awareness .	21	0	4.3	4.3	4.4	4.3	10	11	2.1	2.1	3.0	1.5
Creative expression	20	1	4.0	3.7	4.2	4.3	13	8	2.2	2.3	2.5	1.8
Communication skills . . .	21	0	4.2	4.2	4.4	4.0	15	6	2.3	2.5	2.0	2.3
Technical skills	20	1	3.4	3.1	3.4	4.3	21	0	4.1	4.1	4.6	3.5
Self-confidence building .	20	1	4.4	4.3	4.2	5.0	17	4	2.9	2.9	3.2	2.5
Computation skills	18	3	3.1	3.1	3.2	2.8	21	0	4.4	4.3	4.6	4.3
Engineering fundamentals	14	7	3.2	3.7	3.0	2.8	21	0	4.4	4.3	4.8	4.5
Organizational skills	21	0	4.4	4.4	4.2	4.5	15	6	2.3	2.5	1.0	2.0
Leadership skills	18	3	4.3	4.3	4.2	4.3	8	13	1.9	2.5	1.5	1.0
Planning skills	21	0	4.4	4.3	4.4	4.8	16	5	2.1	2.7	1.3	1.5
Professional ethics	19	2	3.8	3.9	3.8	3.5	14	6	2.5	2.9	2.4	2.0
Engineering judgment . . .	20	1	4.1	3.6	4.6	4.5	19	2	2.9	3.1	3.0	2.3
Quality Scale:			n=21	n=12	n=5	n=4			n=21	n=12	n=5	n=4

Excellent = 5; very good = 4; good = 3; fair = 2; poor = 1

to develop Engineering Judgment in the experiential program whereas students rate the quality of their experience as good but feel that other skills are better developed in the experiential program. None of the groups feel that the opportunity to develop Engineering Judgment is particularly strong in the regular program. Engineering Fundamentals and Technical Skills which are rated as the most important by the faculty, receive extremely high quality ratings in the tradition program from both students and faculty. Organizational Skills and Leadership Skills represent a high quality learning outcome from experiential education, but are not regarded as necessarily important by the WPI respondents.

It is interesting to note that the skills which faculty rate as most important receive the highest quality ratings in the traditional program, i.e., the classroom; whereas those skills which students value most highly receive their highest quality ratings in the MQP and IQP. In general, the traditional and experiential programs are well-matched complements which together provide the student with the opportunity to develop important engineering skills.

The Learning System

There are some important dimensions to the experiential program at WPI. Three aspects of the MQP and IQP have been singled out: 1) the selection of projects; 2) student/faculty/client interaction; and 3) the assessment of student performance.

It is difficult to succinctly yet comprehensively describe the choice of the many different types of projects which students take on. The vastly different purposes of the IQP and the MQP are reflected in the way students make their choices. Except for the Washington, D. C. projects, there is no standard project selection process. Students are encouraged and free to pursue a topic or potential project which interests them. For the IQP, students may respond to a professor's "Project wantad" on the WPI closed circuit TV system. Other students may become interested, for example, in the energy needs of the Northeast and then seek out a professor who would be willing to advise them. For the MQP, students usually work closely with their faculty advisor in selecting this project.

Students are encouraged to prepare a proposal which defines the problem, carefully states expectations, and lays out the limitations and constraints of the project. To prepare students to write such proposals, short courses in proposal writing are offered. One of these courses, is required for all students who have been selected for the Washington internship center.

Although not all projects at WPI are client-oriented, students who work with clients are extremely enthusiastic about their interactions with them. Seven of the eight students responding assign their relationship with the client the highest possible rating, "very satisfied." Student interaction with faculty illicits a mixed response from students with six of twelve saying that they were only "somewhat satisfied" in the relationship with their supervising professor. The more intense contact between students and faculty as well as the openended nature of many projects creates a student/faculty interaction which can be problemmatic. It also can result in a faculty-student partnership which is extremely satisfying to both.

Overall, students gave the experience dimension of the WPI curriculum extremely high marks, with 10 of 12 students saying they were "very satisfied." In contrast, three-fourths of the students who were interviewed indicated that they were only "somewhat satisfied" with the traditional portion of their program. Although students are mixed in their satisfaction with faculty and the traditional program, these WPI undergraduates are very satisfied in their relationships with their clients and their overall project experience.

From the clients' perspective, most students receive a realistic picture of the working world. The supervision of students "on the job" varies. In some cases, students work closely with clients, much as if they were a fulltime employee, while in other projects students work as if they were consultants to the firm. Faculty see their role in projects as inserting an important quality control mechanism and maintaining communication with the client. This student/faculty/client interaction is a totally unique experience in engineering education. For a project to be successfully completed and the maximum educational benefits to be obtained, this three-sided relationship must be carefully articulated and monitored by all the parties involved.

The PLAN system has three "grades" associated with it. The highest grade one can receive is the acceptable with distinction (AD); all other passing work receives an acceptable (AC) grade. If a student drops out of a course, no record is entered on the transcript except in the case of projects where it may be noted that a project was not acceptable. Five of the six faculty members interviewed felt that the grading system should be changed citing that there is little motivation for students who cannot achieve an AD grade. The students, however, seem relatively satisfied with this grading system. They comment on its inexactness, but eight of the 11 responding indicated that they were "very satisfied." Half of the students did point out that they were not aware of the criteria on which they were graded. In summary, the ACAD grading system leaves something to be desired from the faculty perspective whereas these students seem relatively satisfied with it.

Teaching/Learning Rules

It is difficult to discuss the new learning and new teaching roles at WPI without discussing the entire PLAN curriculum. With the introduction of the PLAN and the radically new graduation requirements, students and faculty now interact in a totally new and different way. Major emphasis has been placed on the completion of the IQP and MQP for graduation. In addition, the competency exams in one's major field are obviously regarded by the students as extremely important.

The unique student role literally begins with the admission process in which students may self-admit themselves to Worcester. The interaction with faculty members on projects as well as the new grading system defines a different perspective for the student. In our interviews a number of students commented that because of the PLAN they specifically chose WPI. Students indicate that they spend a great deal of informal time with faculty members getting critiques of their work, planning future activities and using the faculty member as a academic resource to help them over the hurdles of a difficult problem.

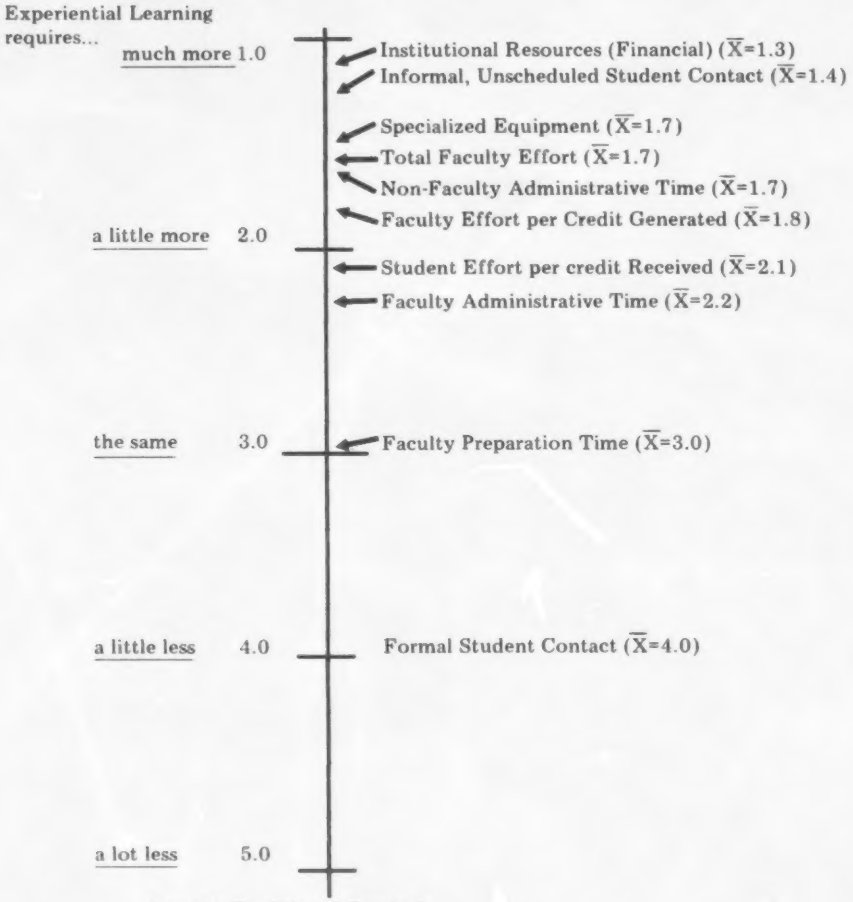
The program inventory in Table 6.3 demonstrates the increased amount of informal student contact and the lessening of formal student contact which occurs in projects. Faculty members and administrators obviously feel that the total effort expended is greater in project work. They also believe that the student effort per credit received is higher. It is interesting to note that they feel faculty preparation time remains about the same. From the learning inventory (Table 6.2), it was discovered that the students feel they are better able to learn Engineering Fundamentals and Technical Skills in the regular curriculum. In essence they are saying that the informal contact which is supported by the data on Table 6.3 is not a good environment for learning these skills. If faculty are best able to teach Engineering Fundamentals and Technical Skills in the traditional program and the nature of the project rather than faculty interaction is responsible for the learnings from projects, one might question whether faculty time is being well spent in these projects. In summary, there is little doubt of the tremendous impact that experiential learning at WPI has had on the role of both faculty and students.

Supplementary Outcomes

In addition to the direct learning outcomes experiential learning may have many spin-off effects or second order outcomes. These may differ for faculty, students, and clients. Faculty commented they had an opportunity to expand their personal development, to increase their consulting opportunities, and to participate in expanded research projects as a result of the experiential component of the curriculum. The new and different set of inputs kept them "sharp" and gave them an opportunity to get into new fields of study. The projects sometimes led to substantial grants to continue research in an area. In addition, faculty often involved students in their personal research projects as part of the student's MQP. This has a disadvantage of not involving a student with a client; however, it gives the student first-hand knowledge of working in-depth on an academic research project.

Clients indicated that the projects gave them an opportunity to get a low

TABLE 6.3
PROGRAM INVENTORY* WORCESTER POLYTECHNIC INSTITUTE



***The program inventory was developed to diagnose, however impressionistically, important differences between the experiential and traditional curricula. Ten key items on which to explore differences were selected. They appear on the right hand side of the table. Respondents scaled the items from 1-5 depending on how much more of the item was demanded by experiential education in comparison to the traditional classroom setting. The scale is represented on the left hand side of the table.**

priority problem solved. Problems that would normally be shelved because of lack of human resources were given to a student team. Clients indicated that project solutions expanded their knowledge more than they had anticipated, and one client commented favorably on the publicity that the company had received as a result of the projects.

A number of students commented on the unexpected benefits they received from their project experience. Some were pleased at the level of enthusiasm they felt as a result of participating in the projects. Students were aware of the general benefits they received for job placement and also enjoyed becoming an expert in a specific area of study. For example, one group of students received the patent rights on an artificial limb and had been requested to speak at conferences.

The MQP and IQP have a significant impact on the attitudes which students possess towards engineering. In-depth experiences in a specific field provide students with an opportunity to realistically evaluate their personal interests in pursuing study and work in a particular area or industry. Students indicated that project experience had in some cases increased their commitment to engineering and had really given them an opportunity to understand the day-to-day activities of engineering. Other students found that they tired of the attitudes of engineers. In summary, the students are highly satisfied with the MQP and IQP experiences; although these experiences may have led to a change in their attitudes about engineering.

Summary

The WPI PLAN has resulted in sweeping changes to every facet of campus life. Students now focus on competency exams in their major field of study, project experiences, and real engineering problems. The experiential dimension of the PLAN, the MQP and the IQP, are complementary with both the regular curriculum and with each other. From the regular curriculum the students learn Engineering Fundamentals, Technical Skills and Computational Skills. In contrast, the projects develop Communication Skills, Interpersonal Awareness, and Planning Skills and Organizational Skills. The IQP and its social-science emphasis adds a new dimension to engineering education and forces students to view societal problems from a different perspective. Through the MQP students get intensely involved in their major field of study. In general, students enjoy their interaction with clients. It was observed that the students in non-client based projects did not possess the enthusiasm nor did they receive the spin-off benefits that characterized client-based projects.

The IQP presents some distinct challenges. The humanistic approach and the social-science emphasis of these projects introduces a distinctly different element to the engineering curriculum and places faculty members in a role which is uncommon to them. These factors result in an IQP experience that is frequently less well organized than the MQP.

It is useful to focus on the strengths, weaknesses and challenges of the WPI experiential curriculum as perceived by students, faculty, and administrators. Because of the unique working relationship in project teams and the interaction with clients, students have an excellent opportunity to develop their interpersonal skills. As one student said, "Students learn how to communicate and work with other people as a team." This is perceived as a major strength of the program. The unique interaction between students and faculty as partners in the learning process is also frequently cited as a strength; and as one administrator said, "(This program provides the) opportunity for close cooperation between teacher and student." Students also appreciate the opportunity to develop their self-confidence and gain an awareness of their personal strengths and weaknesses. Project experience enhances this. Finally, students and faculty cite the opportunity to creatively tackle a real world problem as a strength of the program. One student commented, "(You can) apply material learned in courses to actual problems."

Although most weaknesses cited were extremely specific and did not fall into broad categories, two general themes did emerge. The new demands which are placed on the faculty by The PLAN are significant, and the students perceive the inability of some faculty members to respond to this change as a weakness. For example, students said, "Faculty competence doesn't always match student projects" or "Projects require an open-door policy for proper student-faculty interaction and faculty are not always up to the demand." The second weakness focuses on the general area of project "operation." Students perceive that without proper guidance by faculty projects can be "deadends." Some students see projects as an inefficient use of their time to learn skills.

The challenges for the WPI PLAN are not insignificant. Many respondents mention financial concerns, citing the added costs involved in both developing new projects and maintaining existing project activity. Faculty members and administrators indicate a general concern for the acceptance of this curriculum by ECPD. In addition, faculty see the challenge of redefining the faculty workload to reflect project activity and increased demands it places on them to develop new skills. Finally, the whole concept of project learning is going through a shake-down period at WPI. New projects must be continually developed for incoming students. All of this must be done in the context of reviewing the purposes of the IQP and MQP, relating them to classroom activity, and providing the student with a coherent and comprehensive education.

The PLAN is an exciting, campus-wide innovation which is still in its developmental stages. It is a radical change in engineering education which utilizes a unique curricular format with experiential learning and emphasizes a societal perspective in an attempt to have tomorrow's engineer meet the contemporary world on its own terms.

7

The West Virginia University Pride Program

The PRIDE program, or Professional Reasoning Integrated with Design Experience, is a curriculum revision within the Department of Chemical Engineering at West Virginia University. The basic purpose of the program is to integrate theory and application in the learning process to better prepare students for employment in industry. However, unlike the other programs in this study, PRIDE does not utilize any direct client or industrial experience. The "real world" is brought to campus by simulated, open-ended problems, given to students as projects.

History

The need for this revised curriculum began with a thorough questioning of the abilities and skills that were involved in professional practice. Four areas of goals become clear: Content, Applications, Laboratory, and Communications. With the sponsorship of Exxon Education Foundation, the goals were translated into a learning system, and the first sophomores were enrolled in 1971.

PRIDE is required of all chemical engineering students, however, it builds on the Guided Design program, a two-semester course sequence required of all engineering freshmen. Guided Design is a tightly structured, instructor-programmed, problem-solving course which acquaints all first year engineering students with this open-ended approach to learning. Simulated problems are given as projects to be solved, and thus begins the first experience with this education approach. Guided Design was a forerunner to the PRIDE program and helped to make the latter's establishment a smooth one.

Program Description

Like Guided Design, PRIDE involves small group work on open-ended, industry-like problems, created by the faculty. The program involvement increases from two credits per term in the sophomore year to six credits per term in the junior year, and finally to ten credits per term in the senior year. The format emphasizes project work during class-time, with student self-study of content outside of class, aided by faculty tutorial help. This progression of involvement includes the entire curriculum and is comparable to the increasing number of courses taken in the major.

The flow of the program begins with close guidance and extensive feedback on two projects per term in the sophomore year and ends with a year-long, very large and loosely defined problem in the senior year. Faculty input declines as student leadership increases with each project. Approximately 40% of actual class time is spent on projects and 60% on traditional course work. In the junior and senior years, "blocks" of time are obtained by scheduling certain content classes back-to-back, and then concentrating on a set of objectives (content or project) over the course of the day. This facilitates the integration of the project into the class learning activities.

During the sophomore year students are given very specific engineering problems. Professors carefully monitor a student's progress via group and individualized feedback. The sequence of student activities has been carefully designed and the student is given specific instructions for the next task. It is not until the final two months of the sophomore year that students are given a completely, "open-ended" problem in which they must determine the constraints and work totally on their own. At this point, students work in four-person groups to tackle these problems.

In the junior year the faculty plays a smaller role in guiding the students through their design problems. Two related courses of six credit hours/semester are involved and students continue to work in small groups in solving open-ended design problems. Because each of these problems has no single right answer, student groups may eventually be working on quite different solutions. The commonality of activities that was evident in sophomore classes disappears. This obviously alters the role of the faculty member, as he must be prepared to deal with many more complexities as students probe problem solutions.

The senior year curriculum is expanded to ten credit hours per semester and includes four projects--one, year-long, five to six credit-team project; and three, intensive, 5-14 day projects or "major exams" which are completed individually. In this final year, Tuesdays and Thursdays are set aside for the students to work on their own with little assistance from the faculty in the design aspects of the problem solution. The faculty serve as expert resource people, perhaps even lecturing in their traditional role as content authority. The students are concurrently enrolled in two or three traditional courses. Oral reports and written "major exams" are an important part of the learning process. At the completion of each project, a "verbal" defense and explanation of the group's work is presented before at least two faculty. The faculty becomes more critically demanding of student professionalism as students gain problem-solving experience. Written exams in major content areas are given at least three times per semester. Also communication skills are examined in all reports and a staff person works with individuals to increase oral and written reporting capabilities. Thus, student progress in both the academic and experiential components is monitored.

From the curricular perspective, traditional subject areas are studied by utilizing programmed instruction books, standard texts, lectures, and study guides. Faculty team-up to both teach and evaluate courses, dividing these functions within the same course. In sum, the curriculum is classic in content but innovative in its process.

Program Objectives

From the point of view of those who participate in PRIDE, its primary purpose is educational. Sixty percent of the faculty underscored this objective, while another 50% added the practical experience gained as another important purpose. There was, however, no overwhelming concensus about the objectives from the faculty perspective. Students were even less sure about PRIDE' goals prior to their enrollment. Only three of the 13 students interviewed could list the benefits they expected when they entered PRIDE. Of these three, there was some agreement on PRIDE's attraction for them. Its educational uniqueness, via practical professional problem-solving, was the common expectation. Students may lack opinions on this question because PRIDE is required of all chemical engineering students and because it is highly integrated into the curriculum. For most students, it is a stimulating course they look forward to taking without much prior concern about what it will bring them.

To measure these general expectations in terms of specific skills, the respondents listed the relative importance of possible student learning outcomes. As Table 7.1 indicates, students feel that engineering judgment, problem-solving skills, and technical skills are the most important qualities they will need as engineers. Faculty concur, for the most part, rating communication skills and engineering judgment highest, with problem-solving skills and engineering fundamentals in close succession. Taken together, both faculty and students value the ability to cope with openended problems coupled with the technical engineering skills required to solve the problems. Given the strong contact between faculty and students, such congruence is not surprising. However, alumni also underscore many of the same qualities. Creative expression, engineering fundamentals, and engineering judgment received the

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highest possible rating (4.0) indicating that alumni feel these skills were of "crucial importance." An interesting note is that alumni stress the importance of creative expression, while current undergraduates believe many other skills to be more important. Perhaps the lack of "real world" experience, which alumni have, explains the discrepancy here. In general, however, alumni reconfirm the faculty and student sense of the skills that practicing engineers need.

TABLE 7.1
LEARNING INVENTORY
WEST VIRGINIA UNIVERSITY

Personal Opinion of
the Importance of the Skill or Quality

	Stud.	Alum.	Fac.
Problem-solving skills	3.4	3.6	3.6
Interpersonal awareness	3.1	3.0	3.2
Creative expression	3.1	4.0	3.5
Communication skills	3.2	3.6	3.8
Technical skills	3.3	3.6	3.6
Self-confidence building	3.1	2.6	3.6
Computation skills	2.6	3.6	3.3
Engineering fundamentals	3.2	4.0	3.6
Organizational skills	3.1	3.3	3.2
Leadership skills	2.8	3.3	2.7
Planning skills	2.7	3.6	3.3
Professional ethics	2.7	2.6	3.4
Engineering judgment	3.7	4.0	3.7
	3.0	4.0	4.0

Crucially important = 4; very important = 3; somewhat important =2; not too important = 1.

Program Outcomes

Moving from the desired to the real, let us look at actual learning outcomes from PRIDE, Table 7.2. From the student's perspective, the PRIDE experience is very strong in giving them the skills of interpersonal awareness, problem-solving skills, creative expression, and leadership skills. Faculty concur in many areas, noting that PRIDE's provision of problem-solving skills, interpersonal awareness, communication skills, organizational skills, leadership, and engineering judgment is very good. Alumni agree on the high quality of the engineering judgment and interpersonal awareness in PRIDE, but also add communication skills, and creative expression as opportunities even better achieved in PRIDE. The repetition of interpersonal awareness in all three constituency ratings speaks to its significance. In addition, alumni and faculty agree in the importance of communication skills and engineering judgment, while current students and faculty stress problem-solving skills. Students and alumni do not duplicate each other in many areas. Particularly in self-confidence and engineering fundamentals, students assess PRIDE's provision of these skills a full point higher than do alumni. Students and faculty seem to feel PRIDE does a slightly better job of providing all of the skills than do alumni, but this may only be reflective of their more total, immediate involvement in the program. In general, 62% of PRIDE's students are satisfied with the experiential component of their education (X of 3.4 on a four point satisfaction scale).

This solid satisfaction appears less characteristic of the experiences this sample had in the traditional curriculum as Table 7.2 indicates in the right hand column. Faculty and students rated the provision for development of interpersonal awareness and communication skills as "fair" in the traditional setting, and faculty and alumni gave the same rating to professional ethics. Students, on the other hand, felt that the traditional setting did a much better job at ethics than did the experience dimension of their education (3.5 versus 2.5, respectively). Students also felt that the traditional setting consistently gave lower quality experiences for most skills which PRIDE seems to do best, as the exerpt Table 7.3 reveals.

Finally, it should be noted that the traditional setting provided some skills with higher quality than the non-traditional. In Table 7.2, note that students, faculty, and alumni felt that computation skills were better handled in the traditional curriculum. Faculty and alumni agreed that engineering fundamentals were also of a slightly higher quality in this mode. The high rating of problem-solving skills by both faculty and alumni (3.6 and 4.0, respectively) emphasizes the ability of the traditional setting to teach more than just technical skills.

In general, there seems to be more agreement between faculty and students in these ratings than exists between alumni and either group. The alumni also

TABLE 7.2

LEARNING INVENTORY – WEST VIRGINIA UNIVERSITY

Skill or Characteristic	Experiential Program						Traditional Program					
	Existence of Developmental Opportunity		Average Quality Rating				Existence of Developmental Opportunity		Average Quality Rating			
	Yes	No	All	Stud	Fac	Alum	Yes	No	All	Stud	Fac	Alum
Problem-solving skills	23	0	4.2	4.1	4.4	3.7	22	1	3.4	3.1	3.6	4.0
Interpersonal awareness	22	0	4.2	4.2	4.1	4.0	9	12	2.3	2.0	2.2	3.0
Creative expression	22	0	4.0	4.1	3.8	4.3	10	11	2.4	1.7	2.8	2.5
Communication skills	22	0	4.0	3.7	4.1	4.7	10	12	2.4	2.0	2.2	3.5
Technical skills	23	0	3.2	3.2	3.1	3.5	20	3	3.5	3.3	3.7	4.0
Self-confidence building	22	0	3.6	3.6	3.8	2.7	15	7	2.9	3.0	3.0	2.5
Computation skills	22	0	3.5	3.7	3.4	3.0	22	0	3.9	3.9	4.1	3.7
Engineering fundamentals	20	2	3.5	3.6	3.5	2.5	19	2	3.6	3.1	4.1	3.3
Organizational skills	23	0	3.8	3.7	4.1	3.5	13	9	2.7	2.6	2.6	4.0
Leadership skills	22	1	3.8	3.9	4.0	3.0	6	15	2.5	2.0	2.5	3.0
Planning skills	22	0	3.6	3.7	3.6	3.0	13	8	2.5	2.8	2.2	2.5
Professional ethics	14	6	2.8	2.5	3.1	-	7	12	2.4	3.5	2.0	2.0
Engineering judgment	23	0	3.9	3.8	4.0	4.0	16	5	2.8	2.8	2.9	2.7
Quality Scale:			n=22*	n=9	n=9	n=3			n=22*	n=9	n=9	n=3

Excellent = 5; very good = 4; good = 3; fair = 2; poor = 1

*One administrator appears in the group average that does not appear in any constituency figures.

seem to give slightly higher ratings to the traditional system than do the other two groups. This project does not explain that trend, nor do we know if it is a meaningful one. In any case, this data does indicate that both the PRIDE and traditional programs have strengths, weaknesses and commonalities.

TABLE 7.3

A Selected Comparison of Student Quality Ratings

Skill	X in Experiential Program	X in Trad. Program
Interpersonal Awareness	4.2	2.0
Creative Expression	4.1	1.7
Leadership skills	3.9	2.0

Using the importance data in Table 7.1, Table 7.4 compares the experiential to the traditional program for skills students valued most. The students indicate the quality of the PRIDE program exceeds the traditional program. Note, however, that the discrepancy is not as great as the differences for the skills indicated in Table 7.3.

TABLE 7.4

A Comparison of Skills Which Students Value the Most

Skill	X in Experiential Program	X in Trad. Program
Engineering Judgment	3.8	2.8
Problem-Solving	4.1	3.1
Technical Skills	3.2	3.3
Engineering Fundamentals	3.6	3.1

The Learning System

Within PRIDE the "real-world" experience is gained by student involvement in simulated, industrial issues, created by faculty. Five of six faculty defined a good project as one which applies theory, while one member added problem design as another important characteristic. For the most part students are pleased with their projects. Eight of thirteen students (62%) indicated "very satisfied" while three (23%) stated they were "somewhat satisfied." Consequently, it would be safe to say that faculty seem to do a good job in creating projects and most students are satisfied.

Students seem slightly less pleased with their relationships with their supervising professors. Six of thirteen (46%) said they were very satisfied with that relationship, but five (39%) described themselves as only somewhat satisfied. Finally, two students (15%] characterized themselves as somewhat dissatisfied. The dissatisfaction seemed to relate to the nature or frequency of contact with faculty. For example, "He's hard to corner" or "He's got so many other things to do that he's not interested in my work" are typical comments explaining the criticism. There seems to be a broad spectrum of feeling on this issue and varies among individual faculty.

From the faculty perspective, five of seven faculty said that their involvement with student projects contributed to their own personal development. This kind of involvement is refreshing, challenging and valued by the faculty of PRIDE. The team instruction which divides teaching and grading responsibilities in the course between two instructors is an enriching implication in the program.

Assessing student performance is another key aspect of the learning system. Students in PRIDE seem to have very different experiences in the evaluation of their projects. Only five out of eleven (46%) said they were aware of the evaluation criteria before they began their projects. Nine students (82%) stated that they did receive non-graded critiques of their work, but other faculty were twice as valuable as faculty advisors to the students in this informal setting. Finally, ten of thirteen (77%) felt just "somewhat satisfied" with the assessment process, recording a mean of 2.9 on the four point satisfaction scale. Explanatory comments cite an "ambiguous, secretive process" or "lack of consideration for group work" as issues the current system faces.

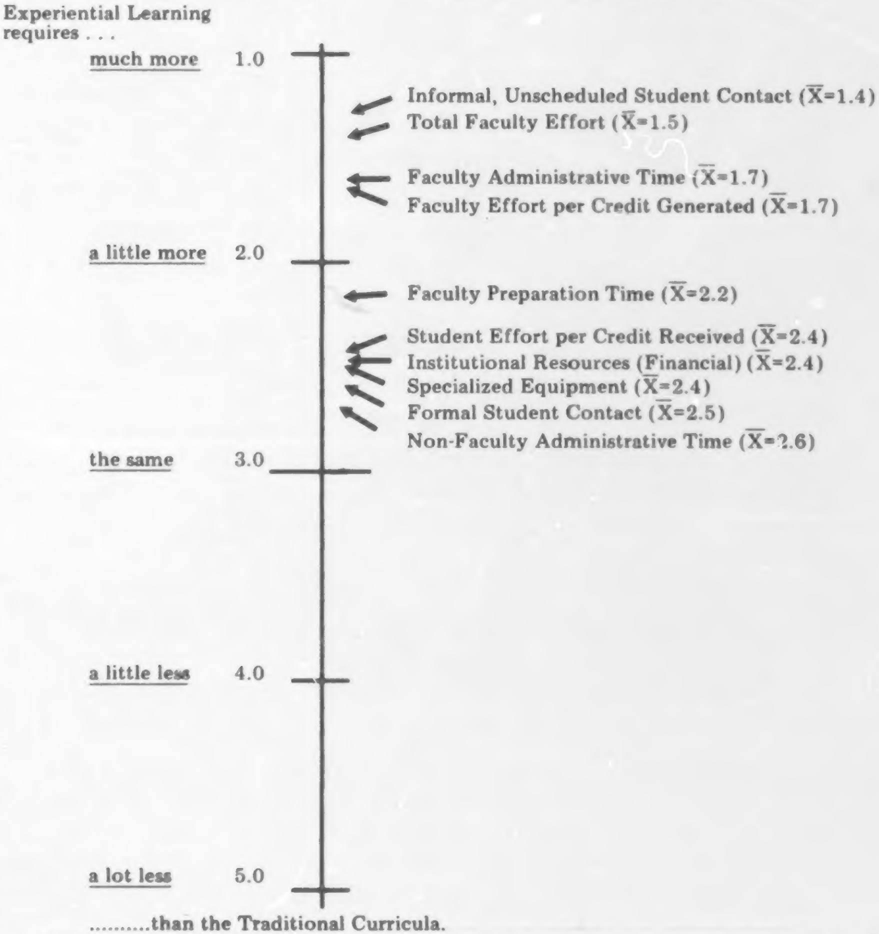
Faculty also criticized the current system, with five of nine (56%) supporting some change in its functioning. For the faculty, subjective criteria predominate the grading, yet a significant number (44%) also apply formal criteria. This merely points out that different faculty use different systems of grading. Three faculty members state that students are informed of the grading criteria, while four did not know if students were told this. The faculty are aware of this issue and probably more sensitive to it than professors in traditional classrooms, where criteria may be long-standing and easily defined. It is to PRIDE's credit that their concern on this issue is apparent and oriented toward change.

Teaching/Learning Roles

Because the learning process is a new one, many different and sometimes unexpected experiences confront faculty and students in PRIDE. The faculty role is affected by new time and attitude demands, as summarized in Table 7.4. It would appear as though most duties have changed, with total faculty effort a good summary descriptor. An experimental system does demand more time and effort! Specifically, six faculty mentioned their prime student responsibility as an academic resource. Another three stressed their evaluative role, and two

TABLE 7.5

PROGRAM INVENTORY* UNIVERSITY OF WEST VIRGINIA



***The program inventory was developed to diagnose, however impressionistically, important differences between the experiential and traditional curricula. Ten key items on which to explore differences were selected. They appear on the right hand side of the table. Respondents scaled the items from 1-5 depending on how much more of the item was demanded by experiential education in comparison to the traditional classroom setting. The scale is represented on the left hand side of the table.**

added the role of academic friend. These responsibilities are very different from a classic content authority role which many traditional faculty assume.

Faculty are expected to possess new skills in order to handle these new responsibilities. When questioned about this, over half of the faculty wishes they had more industrial experience to enable them to better serve PRIDE. A third of the faculty stressed interpersonal skills as a skill they would like to possess or improve. Two of the four administrators interviewed echoed that openness in faculty attitudes and interpersonal skills were special and necessary commodities for faculty in this setting. It is not enough for faculty to give extra time to PRIDE, they must also give new dimension of themselves.

Students benefit in many ways from PRIDE. Over 90% of the students feel they have a more realistic impression of engineers because of their PRIDE experience. For 58% of the students, an increase in positive attitude about the profession ensued.

Half of the students in our sample experienced some unexpected outcomes from PRIDE. Of these students, 67% described the "surprise" as professional in nature. Seventeen percent stated PRIDE was a more personally rewarding experience than they had expected. However, 50% of the students stated that they were not aware of the skills that PRIDE would demand before they began the program. Finally, 54% of the students feel more committed to an engineering career because of PRIDE. A taste of the real world improved the desire to be part of it.

Summary

PRIDE is a unique experiment, both in terms of traditional settings and in terms of experiential programs. It brings in the "real world" by simulation, but nontheless, seems to encompass it well. The sequencing of two credit, six credit, and 10 credit project experiences superbly prepares the student for increasing amounts of autonomy, creativity, and competency. The faculty teamwork in multi-level instruction, enriches both faculty and students. The communication component is individualized and handled by one staff person, yet applies to all classes. Students thus become partners with faculty and staff, and together they approach the teaching and evaluating functions.

Needless to say, all programs can be improved. Students and alumni suggested more rigorous academic standards and better projects. Faculty agreed overwhelmingly on academic content improvements, in both quality and quantity. However, they also unanimously felt that the experience dimension should not be limited in any way. Two of the three administrators in the sample also underscored the need for academic rigor in PRIDE. This appears to be not as much a reaction against PRIDE, for our survey indicated positive feelings about the educational experience in PRIDE. Rather, the comments indicate a questioning of the process; a concern with the program's relationship to the traditional. This is healthy and is found in any experimental setting. It suggests the need for consistent monitoring of the combinations of basic content and experience-based learning in PRIDE.

The strengths of PRIDE are many. Almost 80% of the students listed its interpersonal aspects as PRIDE's major plus. The chance to deal with the real world was a close second in the minds of all who know PRIDE--faculty, alumni, administrators and students. While fewer students stressed the skills that PRIDE imparts, this was a basic strength in the eyes of the majority of faculty, administrators, and alumni. The educational goals of building student self-confidence, learning of the problem-solving process, and succeeding in group work seem to happen. PRIDE delivers what it promises.

With an eye to the future, there are some challenges for PRIDE. At least half of the faculty, administrators, and alumni, respectively, see the major issue as an administrative one, i.e., the internalizing of the program. University support as well as internal program improvement and change are issues that present a challenge. All of the students and most of the alumni consider the major issue to be an academic one. The integration of theory and practice is, and will be, the dominant topic of discussion in PRIDE's educational future. Possible decisions which reflect this issue are: should clients be incorporated into PRIDE; should there be more individual projects; should courses be more computerized; should fundamentals be stressed more? There is no right or single answer to these questions. Yet, their debate and decision will greatly affect the future of PRIDE.

The careful pedagogical design of PRIDE is impressive. It is a "second generation" experiment, with two graduation classes to its credit. The challenges PRIDE faces are actually those of refinement not creation. PRIDE has a strong foundation of experience to build on which will create a stronger program in the future based on an informed past.

8

The University of Massachusetts ESIC Program

In January, 1973, a segment of the Mechanical Engineering department at the University of Massachusetts began a unique experiment in engineering education. The formal name of the innovation is Professional Practice-Directed Engineering Education (PPDEE) and the aim of its practicum, or experienced-based component, is Engineering Services for Industry and Community (ESIC). The goal of the total program is industry-oriented and prepares students to practice their profession by including the mastery of a fundamental knowledge base, as well as the development of the behaviors and the skills required in quality professional practice. As part of this preparation students work half-time on real problems obtained from local industrial firms and community organizations via ESIC. It is this aspect of PPDEE which demands our attention.

History

The definition and articulation of the specific goals, skills, and behaviors required for engineering practice evolved from three main sources: 1) discussions between Drs. John Dixon and Carl Nelson in their on-going dialogue with faculty peers over their concern for the quality and content of undergraduate engineering education; 2) discussions with a departmental Industrial Advisory Board, composed of twenty members from diverse engineering industries and companies and carried out between 1969-72; and 3) discussions with Dr. Lawrence Weed, originator of the Problem-Oriented Medical Record, at the University of Vermont Medical School. What evolved was the Behavior-Skills-Knowledge curriculum which demanded a whole new mode of learning. The requirements for student development were summarized in three categories:

Required Behaviors

1. reliable
2. thorough
3. analytical soundness
4. productive
5. socially concerned

Required Skills

1. learning
2. communication
    a. oral
    b. written
    c. graphics
3. human relations
4. planning
5. experimentation
6. computation
7. innovation

Required Knowledge Fundamentals

1. mathematics
2. statics
3. strength of materials
4. materials
5. dynamics and vibrations
6. fluid mechanics
7. thermodynamics
8. circuits and controls
9. manufacturing processes
10. engineering economics

These goals and objectives are included in both the academic and ESIC components of PPDEE.

Program Description

In January, 1973, the program officially enrolled its first three students. Since then, it has grown to twelve students, four part-time faculty, and includes approximately fifteen clients through ESIC. From its conception, limited growth, small size, and careful program management have characterized PPDEE. Students may enter the PPDEE any time between their sophomore and junior years. Thus, they come to the program with certain basic departmental and university requirements fulfilled. PPDEE is strictly an option within the

Mechanical Engineering department, not required of its students and/or in other departments. Students apply to the PPDEE director for admission and are extensively interviewed and then chosen for entrance by an informal faculty consensus. There is no firm criteria for admission, except perhaps dedication to a fifty-hour work week and a strong desire to practice engineering. Students backgrounds and abilities are diverse.

Once in the program two activities prevail. Students work approximately half-time on their ESIC problem. They are assigned industry based projects by the faculty, as much as possible on the basis of students' educational needs. A problem-oriented Engineering Record is maintained, detailing the goals of the project; the data base; the design or solution specification; PERT charts and other planning documents; current problem status; results to date; time and money records; and a complete log of project work.

The faculty role is to "coach" the student via the unique audit method of twice weekly reviews of student performance, the Engineering Record, and the academic work component. The faculty auditor is a constructive critic, incisive questioner, and demanding professional. He will make suggestions about project direction, but will not contribute the project solution nor lecture on solutions. While one faculty member is "chief" auditor for each student, faculty do sit in on each others audits and freely contribute to the process.

The student has total client responsibility, both technical and communicative. Most projects are done individually rather than in teams and average about three months in length. Projects include machine design; product design, testing, and evaluation; failure analysis; manufacturing process and equipment design; and value engineering.

The other half of a student's program is acquiring the required base of engineering science knowledge through self-study. Unlike many other programs, this is normally not done in traditional class settings. The student's study is based on the questions/issues/data raised in his or her project, and most students learn most of the required knowledge base this way. Students may take up to one outside (conventional) course per semester to help them with the knowledge base or to satisfy a special interest. However, the majority of learning is done on a self-taught basis, using texts, programmed instruction, and auditor suggestion.

A Learning Record, similar to the Engineering Record, is also kept by the student and is a regular part of the audit. It consists of knowledge objectives (areas of study, principles, processes, ideas studied), confirmation that these topics were mastered; reference notes or problems on topics studied; and a complete personal reading list. Further, the Computer-Monitored Instruction (CMI) system under development will test knowledge progress, diagnose needs, recommend learning resources and record student learning progress for the faculty with a visual display computer terminal.

Other mechanisms such as the Professional Review and "senior" examinations monitor the student's educational progress. The Professional Review is a personal, in-depth faculty-student discussion and evaluation of both the project and academic components. Grades are assigned after the Professional Review at the end of the semester, where project performance, Engineering and Learning Records, and program goals are synthesized and evaluated. "Senior" exams are two part: a written exam on the required knowledge base and an Ability-to-Practice exam, based on the final semester's project and presented before a panel of industry observers.

Program Objectives

Although the faculty, students, and clients saw ESIC's objectives in slightly different ways, the viewpoints were highly complimentary and explained much of the cohesiveness of this program. Fully 82% of the students were in the program for their educational growth, citing the traditional classroom as too boring or too theory-oriented. Fifty-five percent of the student sample also specified professional development, or a chance for a "real world" experience as motivation for involvement in ESIC. The "real world" experience was unanimously endorsed by the faculty as a major objective for ESIC, as was the interpersonal aspect of the program (i.e., to increase student's confidence, thinking abilities, etc.).

What appears is a strong fit between what faculty do and what students want. A new type of educational experience is achieved. Yet, it is the client, in many ways, who actually provides the educational setting, and his motivation is not educational. Almost 70% of the clients stated that "benefit to their industry" was their first objective. This is not a surprise, but it indicates a difference between the educational institution and the business enterprise.

Returning to the student/faculty focus, Table 8.1 displays specific skills that students and faculty most value. There is a strong correlation between the skills rated highly by each. Problem-solving skills, communication skills and engineering judgment were the aspects of their education that students rated most important to them. Interpersonal awareness, communication skills and problem-solving skills were the three qualities the faculty felt to be most important for students to learn. The overlap is obvious, as students also rated interpersonal awareness very high while faculty mirrored with an important rating of engineering fundamentals.

The picture presented is one of high congruence between what faculty and students want to have happen and what the program is established to do. Together they seek a unique type of educational experience, focused on problem-solving and communication skills, with engineering judgment learned outside of the classroom, in the "real world". This strong match of objectives between the students and faculty is a sign of stability with ESIC.

TABLE 8.1
UNIVERSITY OF MASSACHUSETTS
Importance Of Attaining These Skills
Constituency Group Average

	All	Student	Faculty	Admn
Problem-solving skills	3.7	3.7	3.8	3.5
Interpersonal awareness	3.6	3.5	4.0	3.0
Creative expression	3.1	3.2	3.0	4.0
Communication skills	3.9	3.9	3.8	3.5
Technical skills	3.1	3.1	2.8	3.5
Self-confidence building	3.1	3.0	3.3	3.0
Computation skills	3.1	3.0	3.5	3.5
Engineering fundamentals	3.4	3.4	3.5	2.5
Organizational skills	3.3	3.5	2.7	2.5
Leadership skills	2.6	2.9	2.0	2.5
Planning skills	3.6	3.7	3.3	3.5
Professional ethics	3.3	3.4	3.0	3.5
Engineering judgment	3.6	3.7	3.0	4.0
	n = 17	n = 11	n = 4	n = 2

Importance Scale:

Crucially important = 4; very important = 3; somewhat important = 2; not too important = 1.

Program Outcomes

The learning inventory in Table 8.2 compares students and faculty ratings of the quality of ESIC program as an opportunity to learn certain skills. Although a halo effect could be operant, the over-all high assessment of the program's provision of these skills is striking. There seems to be no doubt that the skills are provided, and there is wide agreement that the provision is strong in quality. In general, the faculty feel they (or the program) are doing a slightly better job at providing these skills than do the students, but the gaps are indeed, very minor. The most major discrepancies are related to interpersonal awareness and leadership skills, with faculty giving the higher scores. Nonetheless, the difference is not major. The overall quality is very strong and consensus between faculty and students is apparent.

Table 8.2 also indicates the perceived quality of these same skills as provided in the traditional classroom. A more discriminating profile appears. The table presents not only a quality rating, but indicates whether or not the opportunity to learn was there. The respondents credit the traditional educational setting with having slightly better quality in engineering fundamentals and computation skills. Generally, however, both students and faculty feel that PPDEE/ESIC provides more of an opportunity for achievement of the above skills as well as providing a higher quality experience. This is particularly true of the interpersonal types of skills, such as awareness of others, leadership, and ethics. Simply, in the opinion of these respondents, the less technical the skill, the less likely the traditional classroom encompasses it in quantity or quality.

The students are extremely satisfied with their educational choice. They have consciously opted for the ESIC alternative; they do not regret their choice. Every student interviewed gave a rating of "very satisfied" ($\overline{X} = 4$, on a 1-4 scale) to describe his relationship with his supervising professor, and a similar rating ($\overline{X} = 3.9$) to describe his overall satisfaction with ESIC. While client relationships were only somewhat satisfying ($\overline{X} = 3.3$), the summary comments are very positive.

The Learning System

Three components of the learning system were considered: 1) project qualities; 2) student/faculty/client interaction; and 3) assessment of student performance. The objective was to understand in greater depth what seems to make ESIC such a strong experience for those involved in it.

Project selection is a faculty responsibility in ESIC. Because the project is the basis of learning, the faculty link students with experiences that will teach them what they don't know, rather than what they may be best at. Consequently, 100% of the faculty responded that a **good** project must benefit the student not the professor or client, and that it had to have problem design characteristics. Another characteristic stressed by half the faculty was that of applied theory.

TABLE 8.2
LEARNING INVENTORY — UNIVERSITY OF MASSACHUSETTS

Skill or characteristic	EXPERIENTIAL PROGRAM						TRADITIONAL PROGRAM					
	Existence of Developmental Opportunity		Average Quality Rating				Existence of Developmental Opportunity		Average Quality Rating			
	Yes	No	All	Stud	Fac	Adm.	Yes	No	All	Stud	Fac	Adm
Problem-solving skills	17	0	4.4	4.4	4.3	4.5	12	5	3.2	3.3	3.0	3.0
Interpersonal awareness ..	15	1	4.4	4.1	5.0	4.5	5	11	3.0	3.0	3.0	3.0
Creative expression	14	2	4.2	4.1	4.3	4.0	9	7	2.1	2.0	2.5	2.0
Communication skills	16	0	4.3	4.2	4.5	5.0	11	5	2.7	3.0	2.8	1.0
Technical skills	17	0	3.7	3.7	3.8	3.5	14	3	3.2	3.4	2.7	3.0
Self-confidence building ...	16	1	4.5	4.4	4.5	4.5	9	8	2.9	2.8	2.8	4.0
Computation skills	17	0	3.9	3.9	4.0	3.5	17	0	3.9	4.1	3.8	3.5
Engineering fundamentals ...	16	1	4.0	3.8	4.3	5.0	16	1	4.1	4.1	4.5	2.0
Organizational skills	16	0	4.7	4.6	4.7	5.0	9	7	2.8	3.0	2.5	2.5
Leadership skills	13	3	3.6	3.4	4.0	—	4	12	2.3	1.5	3.0	–
Planning skills	15	0	4.6	4.5	4.7	5.0	9	6	2.3	2.7	2.0	1.0
Professional ethics	17	0	4.2	4.1	4.0	5.0	6	11	2.3	2.5	2.3	–
Engineering judgment ...	17	0	4.4	4.3	4.5	4.5	11	6	2.6	2.8	2.3	2.5
Quality Scale:			n=16	n=10	n=4	n=2			n=16	n=10	n=4	n=2

Excellent = 5; very good = 4; good = 3; fair = 2; poor = 1

Apparently, all clients are chosen on faculty initiative, giving the faculty the opportunity to be sure that project criteria are met. It appears they succeed; explaining in part why student satisfaction with client experience is so high.

In terms of the interaction between client, student, and faculty, another positive picture is found. Clients feel the experience the student gains with them is somewhat (33%] to very (50%) realistic. Approximately 88% of the clients perceived their supervisory role to be minimal, coming at the beginning of the job if at all. Criticisms of the ESIC program from the clients' perspective were not strong, but did touch on these areas: 50% felt that the semester time frame did not fit their working demands; 33% felt that students lacked knowledge of the "business" world, a naivete of sorts. One client was disappointed with the technical/academic background. There was 100% satisfaction with the degree of communication between the clients and ESIC. In general, the clients seemed satisfied with what they offer the student (real world experience) and were satisfied with what they got.

The students also appear satisfied with their client experience although the mean (3.3 on a 4 point scale) was lower than the very high satisfaction expressed by faculty. Specifically cited were improved personal relationships between the clients and students. Despite the focus of ESIC on real world experience, it appears that the most meaningful link between the real and academic worlds is developed by the faculty. It is to the credit of this program that the faculty seem to respect and accept the management role that ESIC operationally necessitates. The faculty were unanimous in stating that their two key responsibilities to the clients were first, to be a liaison with the student and second, to maintain quality control for the student's learning experience. The chief benefits derived from their participation in the projects (again unanimously underscored) were; personal development in a professional way, and, consulting benefits. Research and publication benefits were mentioned by only half the faculty.

The grading and assessment process of ESIC is one of the greatest strengths of this program. The desired behaviors, skills, and attitudes are so clearly enunciated that 100% of the faculty could explain all formal and subjective criteria that affect assessment. Fully 80% of the students surveyed felt that they were aware of the criteria before they actually began the experience component. Further, a mean of 3.7 (on a 4 point satisfaction scale) was given to the ESIC grading and assessment system by the students, indicating their high satisfaction with the process. Generally, the auditor was cited as the person who was seen most often and who gave the most valuable non-graded critiques of an individual's work. No faculty felt the grading system should be changed. The conclusions drawn about this aspect of the learning system are clear; students and faculty are highly satisfied with the assessment procedures, sure of the parameters, and uniform in their implementation.

Teaching/Learning Roles

The ESIC program is very unique and therefore holds a mixture of distinctive structure and unplanned challenge. Table 8.3 summarizes the impact the new program has had on the faculty role.

Students and faculty seem to put more effort and time into the new system. Formal student contact was found to be most changed because of ESIC. However, other items indicate that time and resource expenditure is very similar to the traditional system. All faculty view themselves as academic resources for the students and consider this their first responsibility. Evaluator and academic friend were added as secondary responsibilities by half the faculty. Communication, industrial experience, interpersonal skills, and an attitude of partnership with the student were skills that the faculty consider crucial for them to have in this environment. While it takes a unique person to function in the teaching role here, those who do are committed to the new definitions and responsibilities their faculty role brings them.

Supplementary Outcomes

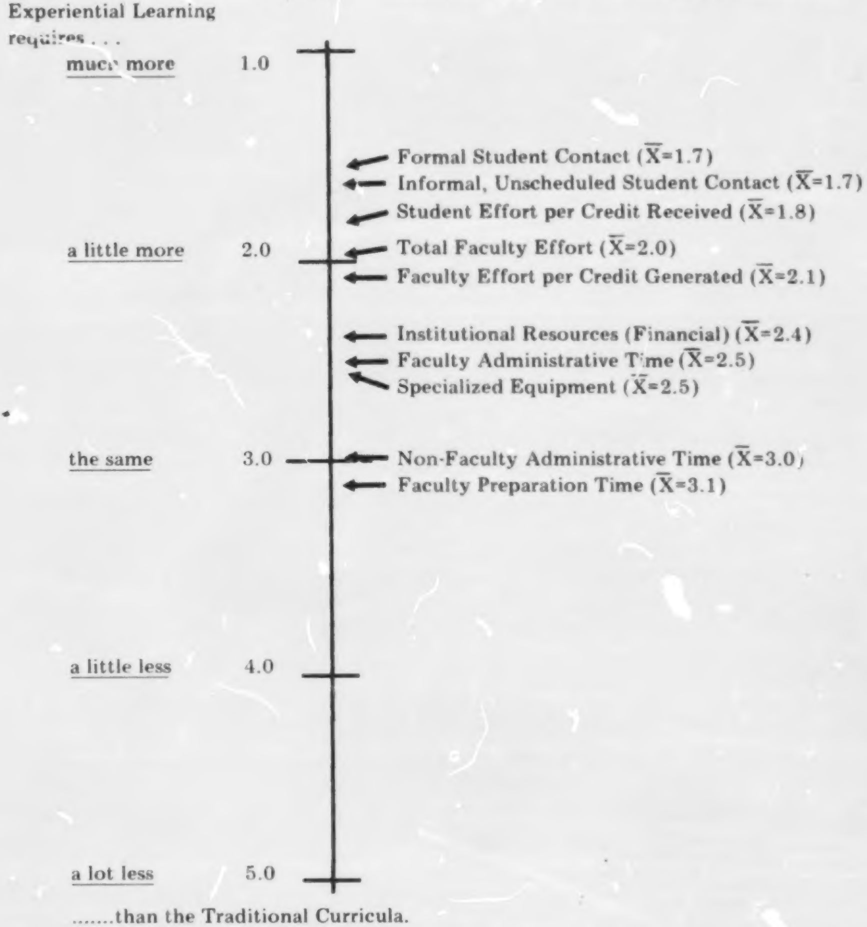
It is important to note the unexpected outcomes, as well as those that were intended. 100% of the clients and 89% of the ESIC students said there were outcomes which they did not expect to have during their involvement in this program. These unintended consequences varied by group. Almost two-thirds of the client sample said they had learned more about themselves because they worked with the students. New inputs brought new viewpoints, and hence, new learning the clients had not anticipated. For the students, the "surprises" were, for the most part, personal, positive experiences they had not expected. For example, being offered a job by the client, knowing that the company usually demanded five years working experience from new employees, delighted one senior. Only one student and one client mentioned a negative experience as the unexpected consequence.

Another type of outcome to examine is the effect the ESIC experience had on the students' attitudes toward engineering and his/her own future career. Every student questioned said that their impressions of engineers had become more realistic because of their client experience, and for 80% of these students, that meant a more positive impression. Seventy percent of the students said their commitment to an engineering career had increased because of the program. It would seem as though ESIC is producing "believers" who are knowledgeable in the realities of the field.

Summary

The ESIC program is radical--it involves no formal classes in its educational system. Rather, the individual semester projects are the center of the learnings. The clarity and assessment of objectives is stellar, and this may

TABLE 8.3
PROGRAM INVENTORY* UNIVERSITY OF MASSACHUSETTS



***The program inventory was developed to diagnose, however impressionistically, important differences between the experiential and traditional curricula. Ten key items on which to explore differences were selected. They appear on the right hand side of the table. Respondents scaled the items from 1-5 depending on how much more of the item was demanded by experiential education in comparison to the traditional classroom setting. The scale is represented on the left hand side of the table.**

explain part of the strong communal feelings which unite all program participants together. The goals are clear and commitment to them is basic. While the student/client relationship could sometimes be improved, in general, we find a strong and true educational alternative in the ESIC program.

Its strengths are many, although each constituency group perceives them differently. For 60% of the students, the interpersonal benefits and personal development aspects of ESIC were cited as the program's greatest strengths. Another 40% of the students felt the experience dimension of ESIC was its major plus. The skills and academics were stressed by another 30% of the population. The faculty, on the other hand, listed faculty development and growth as ESIC's major strength, as did the administrators in our sample. For both faculty and administrators, the experience elements were valued second, closely followed by personal benefits and skills.

The entire picture is a healthy one. Each group finds the program meeting their individual needs first. Both students and faculty grow as professionals and as people. These are not mutually exclusive needs; in fact, quite the contrary. Because faculty are so student-oriented, it is no surprise that their development would be intricately linked to the students. The tight match between strengths and objectives underscores the satisfaction of faculty and students with ESIC.

The clients perceive the strengths of ESIC a bit differently. Almost two-thirds of the clients felt the major benefit was the academic content and half the clients added the skills dimension of the program. However, interpersonal skills and personal development were mentioned as strengths by only a third of the clients. This group also perceives the students' development, as the major strength of ESIC, but in a more technical/academic dimension. Again, this seems appropriate, as the clients' projects are designed to focus the academic substance of this program. Simply, the clients are saying this happens.

We also solicited programmatic weaknesses or concerns. Almost on equal number of students were concerned with the academic aspect of ESIC/PPDEE and wondered if they had enough of the "basics." Seventy-five percent of the faculty were also concerned about this issue and listed the acquisition of engineering fundamentals as the major weakness from their perspective. All of the administrators echoed this concern as did two of the clients. Given the total departure of PPDEE/ESIC from the traditional educational setting this general concern is logical. There is much more pressure to justify the experiment which translates into a concern for the educational outcomes.

In sum, the program is dynamic, thoroughly planned, and well managed. While there are apprehensions about its present and future, the program seems to be healthy and there is a desire for constant improvement. The major issue appears to be credibility within the university and with clients. However, the educational excellence of ESIC should meet this challenge.

9

Program Comparisons

Experiential components of engineering curricula were created to enhance students' professional education--to provide those additional learnings which traditional curricula and traditional learning environments were not designed to promote. Experiential engineering education has emerged in many forms.

This study shows that models and outcomes vary with purposes, that costs vary with formats, and that there may be many "best ways" to structure experiential engineering education. This comparison should lead one to recognize which outcomes are related to which models and which activities within the programs produce particular outcomes. Extra student and faculty effort characterize all programs. Thus, the critical questions which need to be asked then are: Experience for exactly what purposes? What kind of experience? How much experience? At what point should the experience component enter the curriculum? What client/institutional relationship best suits the situation?

A Comparison of the Models

The six programs selected for this study promote similar basic goals. Generally, they are student-oriented goals focusing on learning outcomes at the upper levels of the learning hierarchies as discussed in Chapter 1. Problem-solving skills, engineering judgment, interpersonal and communication skills are among these. The programs vary according to the explicitness and definitional precision of their objectives. Some programs emphasize particular outcomes more than others. Communication is stressed at West Virginia University (WVU); design at Kansas State University (KSU). Harvey Mudd College (HMC), alone, articulates faculty-oriented and college-oriented goals.

Various program formats have been created to accomplish these goals. Table 9.1 summarizes these variations in approach and highlights important aspects of program structure. Some programs are located in a single department while others encompass all departments (line 3). This influences the number of students participating (line 5) and the number of clients involved (line 15). From various levels of participation flow different management or administrative needs. Specialized counseling and administrative personnel are involved at the University of Cincinnati (CINN) for their totally off-campus program, while the program is handled within faculty workloads at KSU.

Experiential learning is funded differently at the various institutions (line 2). Two projects--University of Massachusetts (UMASS) and WVU have received single grants, while Worcester Polytechnic Institute (WPI) has benefited from multiple grants. Two institutions cover modest materials costs through minimal fees (UMASS and KSU). HMC charges client fees which cover all instructional and materials costs. This results in a highly developed and standardized pattern of client/institutional relationships. Instructional costs are covered by internal funds at CINN and KSU. In large part, then, funding is determined by the nature of the client/institution relationship (line 16).

Student participation varies in significant ways. Most programs involve students from their sophomore through senior years (line 4). This covers the major period of the students' intellectual and social maturation while in college. KSU is the exception where students are involved only during their senior year. The amount of time students are actually involved in projects varies from one semester at KSU to almost total involvment at UMASS. Projects range in duration from a term to several semesters (line 6). Students can choose their projects at each institution, except UMASS and WVU. Because projects encompass so much of the curriculum at these two schools, teachers want to insure that students gain broad exposures. Therefore, assignments are made, not negotiated (line 8).

Students receive credit at all schools but CINN, and there, because of employment, students are paid by the companies hiring them. CINN, alone, is a five-year undergraduate program. Students receive grades at all institutions (line 9), yet grading philosophies vary. The team approach characterizes some programs, while at some institutions students go it alone (line 12). This influences some of the learning outcomes, especially leadership. With the exception of KSU, students have a chance to work on more than one project.

The client/student/institution relationship varies with the nature of the "experience" or project. At WVU there are no clients--projects are simulated. At CINN, students are placed in businesses. At UMASS, HMC, and KSU, the client/institution relationship is essentially a consulting or subcontracting relationship, while at WPI the consulting relationship exists along with student industrial or agency placements. Clients can be both public and private

TABLE 9.1
GENERAL PROGRAM COMPARISONS

PROGRAM DESCRIPTORS	Line No.	UMASS	WPI	HMC	CINN	WVU	KSU
GENERAL							
Founded	1	1973	1971	1961	1906	1971	1966
Funded	2	External/Internal/ Project fees	External/Internal	Internal/ Project fees	Internal	External/ Internal	Internal/ Project fees
Location in curriculum							
Discipline(s)	3	Mechanical	All	All/none*	All	Chemical	Mechanical
Level	4	Soph/Jr/Sr	IQP-Soph/Jr MQP-Jr/Sr	Jr/Sr/Fifth	Soph/Jr/Sr	Soph/Jr/Sr	Senior
Approximate student participation per year	5	±16	±1700	±100**	±1800	±330	±45
PROGRAM FORMAT							
Experience project length	6	1 semester	7 weeks academic yr.	1 year + on-going	1 term	5 days — 2 semesters	1 semester
Student participation							
Required	7	No	Yes	Yes	Yes	Yes	Yes
Project preference solicited	8	No	Yes	Yes	Yes	No	Yes
Assessment							
Grades	9	A/B/C/D	A/AD***	A/B/C/D	S/U	A/B/C/D	A/B/D/C
Credit	10	Yes	Yes	Yes	No	Yes	Yes
Compensation	11	No	No	No	Yes	No	No
Team	12	No	Varies	Yes/student leader	No	Yes/student leader	Yes
Faculty participation							
All in department participate	13	No	No	Yes	NA****	No	No
Approximate numbers	14	4		8-10	NA****	6-8	3-4
Client participation							
Approximate numbers	15	±15	±150	±16	±500	NA****	±30
Relationship to college	16	Contractual with school	Contractual with school	Contractual with school	Accept student for employment	NA****	Contractual with school

* HMC not organized into departments
** Includes fifth year masters students.
*** A = acceptable; AD = acceptable with distinction
**** NA = not applicable

institutions or individuals. For those schools with client/institution arrangements, the relationship is consummated with a final written report usually accompanied by an oral presentation.

As this discussion shows, experiential learning activities may be organized in radically different ways. Although these six models possess many similarities, the programs have been organized for different purposes and thus are characterized by different learning activities and ultimately different outcomes or results. The following sections briefly compare the program purposes and philosophies of the six models; discusses the important aspects of this new learning environment; contrasts the six experiential programs along selected dimensions; calls attention to the institutional implications which result from implementing an experiential program; discusses the implications for students by analyzing specific student learning outcomes, the impact which these programs have on professional attitudes, and the degree of student satisfaction; and finally, highlights the common strengths and weaknesses which have emerged from comparing these programs. For the sake of brevity and readability, this chapter has purposely limited its discussion to the distinguishing characteristics of each program. More detail on each program is included in the chapters which discuss each program separately.

Program Purposes and Philosophy

There are common core objectives across all the programs, e.g., relating theory to practice and developing interpersonal/communication skills. However, there are substantial differences in program emphasis. The CINN Co-op program is career oriented; the M. E. Design Lab at KSU has the specific purpose of providing senior students with an integrative, design experience; chemical engineering at WVU focuses on problem-solving with a special emphasis on communication skills; at HMC, WPI and UMASS, experiential education has a comprehensive set of purposes. At these three colleges, engineering design and actual experimentation are often coupled, and the development of professional/personal qualities is emphasized, yet career choice and development are not consciously built into program activity.

HMC and WPI have also broadened their purposes to include a societally-oriented project as a prelude to engineering projects. These programs are specifically designed to expose the student to societal issues and to create "technological humanists" who are aware of the impact that science and technology has on society. The same degree of programmatic emphasis does not exist at the other four institutions.

In terms of "real world" exposure, the programs vary from CINN which arranges off-campus employment, to WVU which creates simulations of "real world" design problems. The other four programs accept "real world" problems from client organizations and solve them in the campus environment.

Only WPI varies from this model, with some of its students actually working in project centers located at the client site. Real world exposure results in a dimension of real world responsibility. The obligations and demands of employment (as a co-op program) differ from the client-consultant relationship of a project. Both of these qualitatively differ from a simulated project environment. What ties these programs together is the essential nature of the project or experience. It requires an enterprising application of engineering theory, it is open-ended, and there are no "right answers."

The Learning Environment

The programmatic purposes and objectives translate into different learning activities for each of the institutions. It is these characteristics of the learning environment which seem to have the most impact on the outcomes of these experiential programs.

Project Duration and Placement

The length and placement of experiential education flows directly from program purposes. At KSU, the Design Lab is viewed as a capstone experience which challenges students to utilize their engineering fundamentals on a design problem in preparation for moving into the working world. At the other institutions the objectives are similar, but project placement and length differ. At WVU, student autonomy and responsibility and the difficulty of the projects gradually increase as students acquire more skills. At UMASS, HMC, CINN and WVU, students participate in projects spread throughout their sophomore, junior, and senior years. As one might expect, a project during the sophomore year may have quite a different impact on a student who knows little about the engineering profession than a senior year capstone experience.

Teams Or Solo

Team versus individual (solo) projects represent an important programmatic distinction. Team projects tend to be more comprehensive and take longer to complete than solo projects. Various interpersonal learnings and leadership skills seem to emerge more readily from the team environment. On the other hand, assessment is more difficult. Responsibility and learning can become diffused, and project management can be complicated. If each student must have a project, it creates demands for more clients and the need for more program administration. There are solid pros and cons on either side of this issue.

Project Selection

Basically the selection of projects is to promote intellectual and interpersonal development. There are two additional important aspects: 1) the soliciting of projects from clients; and 2) the assignment or selection of students to complete these projects. In all programs involving off-campus clients, the faculty and administrators interviewed overwhelmingly indicated that the initiative for project solicitation rested with the institution. Only rarely did a client come to the institution and offer a project. In a sense, however, these data are somewhat misleading. Although initiative undoubtedly rests with the institution, client-institution relationships often become well-established business partnerships and a firm will tend to continue to provide new project alternatives. WPI has established "Project Centers" in a local industrial firm, a local hospital, and in Washington, D. C. These Centers provide continuing project opportunities and may have as many as thirty students simultaneously working on different projects with a fulltime faculty member in residence.

There does not seem to be the difficulty in "selling" projects to clients that one might envision. In a tightening economy, clients indicate it is more difficult to justify the expenditure of even $500 for a project, yet the HMC program continues to generate many projects while charging clients a standard fee for the project's materials and instructional costs. Thus, institution-client relationships are established which are mutually beneficial and provide a continuing source of projects.

Project selection at WPI for "non-client" based problems and at WVU for their simulated projects obviously involves a different set of constraints. At WPI, project definition is frequently left to the students, and they will design their own projects much the same way as one chooses a thesis topic. Problems of interest and ones which are relevant to professional goals are oftentimes selected. For example, one team became intrigued about the energy needs of New England and then went about defining a project that was "doable" within their own personal resources. At WVU, faculty members are responsible for generating all the projects and feel obligated to continually update existing ones. Because of this, faculty cite the difficulty of continually finding new problems which capture the students' interest and are in keeping with the class's ability and skills.

From a student's perspective, project selection varies greatly across the six models. At KSU and HMC, students indicate their project preference. With this information the faculty then create the project teams. At WVU, all students in one course are given the same project and the faculty make team assignments, varying team composition from project to project. At WPI, project selection and team assignment rests almost entirely with the student, whereas at CINN, only after a thorough review of employment alternations and personal career goals, do students interview with prospective employers. At UMASS and WVU, students are assigned projects by the faculty. In these two programs, experiential education accounts for a large proportion of the curriculum. Thus, faculty assign projects to insure that each student receives substantive exposure to a wide range of engineering problems.

The important difference in these models is the amount of student initiative and the resulting learnings and/or frustrations that can occur when students define and select their own projects. Critical to the project selection process is the match between the student's interests and the particular type of project. A good fit between student needs and potential learnings from a project is an extremely critical dimension of experiential education.

Faculty Responsibilities

In each of these models, the faculty role and responsibilities are significantly altered. Faculty overwhelmingly indicate that their primary responsibility is to act as an academic resource with over one-third of them also viewing their role as an "academic friend" or advisor. Although we do not have comparable data from the traditional classroom setting, there was little doubt that this group of faculty members--all of whom have taught in the trditional setting--feel that their relationship and responsibilities to students has changed. They work more intensely with students, oftentimes in a collegial, "roll-up your sleeves and get your hands dirty" environment. Observations of student-faculty interactions revealed a collegial atmosphere not usually evident in the traditional classroom setting, leaving little doubt that the faculty role had changed.

Faculty also must take-on the added responsibility of a client. Fifty-six percent of the faculty interviewed stated that they see their primary responsibility with the client as one of maintaining quality control. Thirty percent of the faculty also indicate that they feel responsible for maintaining student-client contact. Although faculty must act as liaisons, it is still the students who assume the major client responsibility interacting with the client as needed.

As their role changes, faculty members in all of the programs cite the need for an expanding set of skills. To act as an effective project coordinator and resource, industrial experience becomes increasingly important. Similarly, approximately half of the faculty felt the need to increase their technical skills. Even at WVU which does not involve clients, faculty expressed this need. Also, with the increased personal contact with students and a less formal relationship, it is not surprising that 37% of the faculty expressed a need for increased interpersonal skills.

With these new demands come new benefits for faculty members. Nearly three-fourths of the faculty commented that these programs have enhanced their own personal academic development. Working with students on a problem that a faculty member may know little about is a mind-stretching experience. In addition, over 20% of the faculty indicate that project learning results in increased consulting opportunities for them and also increased research benefits.

Assessment of Student Performance

Perhaps no facet of the traditional academic equation is more altered nor is any aspect of experiential learning more potentially problemmatic than the assessment of student performance.

Experiential learning, as with many innovations, calls forth assumptions about learning and its assessment procedures. The interviews revealed that both students and faculty are oftentimes frustrated by the inexactness which they feel in the grading process. This frustration may in actuality be more of a reflection on the traditional system and its assumptions than a difficulty which is inherent in experiential learning. Even so, the criteria of performance are significantly altered in experiential learning. Paper and pencil examinations cannot be given nor is there any unique answer to project problems. Faculty must now evaluate behaviors such as communications skills and organization skills. With team projects it is also difficult to accurately assess the contribution of an individual student. In essence, the standards of accomplishment have been widened to include many on-the-job performance measures which are usually not evaluated in traditional education. The background and experience of faculty allow them to grade student performance along the traditional lines of academic success, but experiential learning calls into play a whole new set of factors.

Some programs have consciously singled out the grading process and revised it to reflect either this new learning format (i.e., WVU, CINN) or a change in institutional philosophy (i.e., WPI, UMASS). WVU's Chemical Engineering Department has purposely separated the teaching process from the assessment process. In sophomore and junior courses one faculty member teaches the Guided Design course while another faculty designs and grades all tests and evaluates project work. For senior projects, students make an oral presentation of their findings to a panel of faculty members who then question them. Faculty in this program believe strongly in the strengths of this ''oral defense'' as do the students, yet both recognize the inexactness of it. At WVU, students comment that they really are not sure of the criteria on which they are being graded and faculty candidly remark that they feel uneasy because they are not sure what criteria apply.

At CINN, the assessment process has been carefully designed to reflect the purposes of the co-op education. The system is highly formalized with both supervisor and student input. On-the-job supervisors are requested to give detailed feedback to the students on their overall work performance and must also submit to the student's career counselor a comprehensive assessment of this individual's performance and professional development. Students must describe their most recently completed job and evaluate their own personal development. This evaluative data then forms the focal point for discussion between students and their career counselors.

At WPI, projects are graded on an "acceptable" (A) or "acceptable with distinction" (AD) basis with an option, for project work, of noting "not completed" on the permanent record. Students and faculty agree that this system is good for project work, but faculty feel strongly that it should be changed for classroom evaluations.

The ESIC program at UMASS has singled out the assessment process as a crucial segment of experiential learning, and taken great care in designing an elaborate and detailed evaluation system which places evaluation at the heart of the learning process. Students are presented an evaluation sheet which outlines the three ares which are evaluated: behaviors, skills, and knowledge. Each behavior and skill is individually evaluated and enters into a determination of the final semester grade. Twice a week students meet formally with faculty to review their assigned grades. Students and faculty indicate a very high degree of satisfaction with this system.

At KSU, the faculty member determines the grade by observing the students' contributions to the team effort throughout the semester. In addition, and most important, faculty members evaluate the presentation to the client in determining the final grade. At HMC, the faculty relies heavily on input from the team leader in determining the final grade with both formal and informal criteria entering into the final determination.

Thus, each of the institutions handles the assessment process somewhat differently. CINN and UMASS have radically altered the traditional grading process to conform to their stated purposes while WPI has deemphasized grading by adopting a two-grade system.

As indicated in Figure 9.2, satisfaction with the assessment process is somewhat mixed with an all-program, mean student response of 3.3 on a 4-point scale. The models receive significantly different responses from their students. Over 70% of the students at both UMASS and WPI indicate that they are "very satisfied" with the assessment process as it currently exists. In contrast, only one of thirteen (8%) interviewed at WVU and four of fifteen (27%) at KSU indicated they were "very satisfied."

When students were asked if they were aware of the criteria which were used to grade them, an interesting mix of responses resulted. Students at UMASS and CINN overwhelmingly indicated that in fact they were aware of the criteria which were utilized; while at WPI, HMC, and WVU there was an even split of those who knew and those who did not. At KSU, only two of 12 students indicated that they were aware of the criteria which were used. These responses reflect the different assessment procedures described above. When faculty were asked if students were informed of the criteria, 21 of 25 faculty across all programs said that students were informed. Obviously, students in some programs feel that they are not being informed of the assessment criteria,

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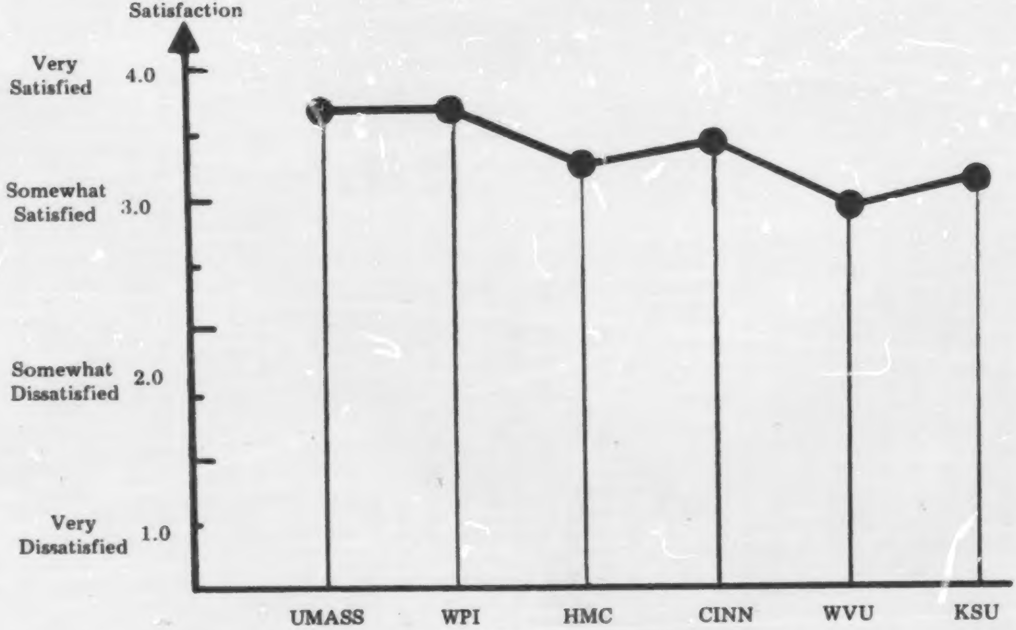
FIGURE 9.2
Student/Alumni Satisfaction
with the Assessment Process
(Average Institutional Response)



while faculty indicate that they are communicating this to students. An agreement on the assessment criteria by both faculty and students means that both groups are working toward the same goals. When students know the criteria against which they will be graded, they can strive to attain the desired learning outcomes. The programs at UMASS and CINN which have singled out the assessment process and carefully defined its criteria, represent a healthy consistency that the other models do not.

The assessment of student performance in experiential learning represents potentially the most troublesome area, yet it also can be one of the most powerful tools in the teaching/learning process. With new outcomes and new educational goals being sought, new assessment procedures are needed. Each of these programs has chosen a different assessment method to reflect their program purposes. A healthy and much needed by-product of experiential learning may be a careful review of assessment processes in education.

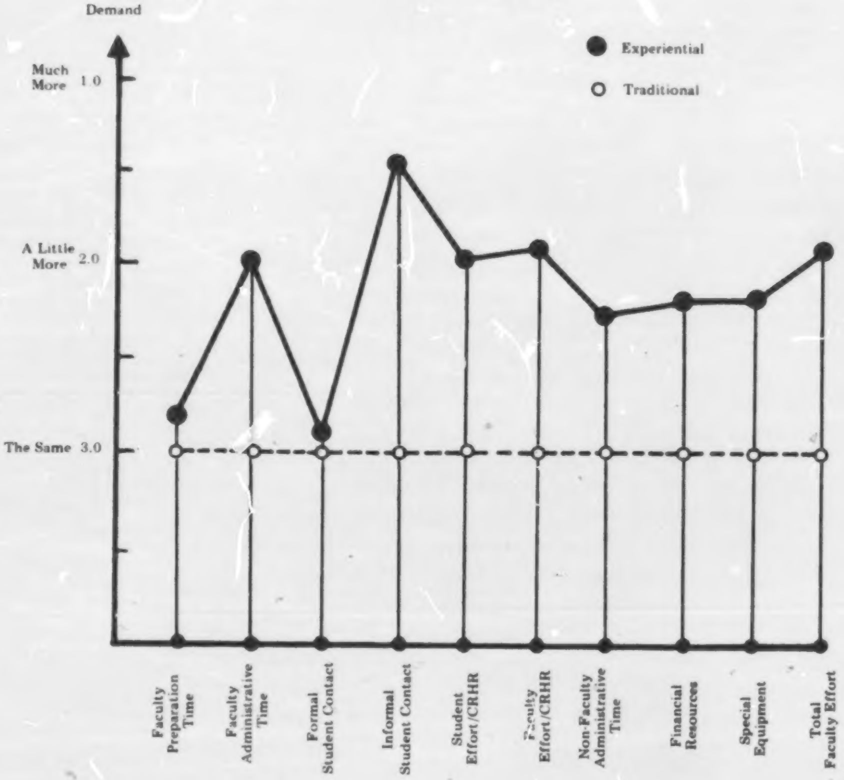
Institutional Implications

As has been shown, each of these experiential programs has a different set of purposes and each has created a somewhat different learning environment. Quite naturally, each model results in different student learning outcomes. What must not be overlooked, however, are the institutional changes which result from implementing such programs. Although this study was not designed to provide an in-depth assessment of the institutional impact of each model, exploratory data were collected. Figure 9.3, compares the change in a selected set of institutional relationships as a result of implementing an experiential program. This information was collected from the personal perceptions of faculty and administrators who had first-hand experiences with these programs.

Note that for all the items in Figure 9.3 experiential learning results in "greater amounts or requirements." Only faculty preparation time and formal student contact remain about the same. Informal student contact, such as unscheduled discussions about a problem, changes the most. Each of these experiential models significantly alters the teacher/learner relationship. This learning relationship translates into more faculty effort. Faculty members find themselves working with the students as colleagues, frequently in technical areas that both may know little about. The intensity of the contact promotes a collegial atmosphere and is also much more demanding.

Figure 9.4 presents institutional breakdowns of the same data discussed in Figure 9.3. An examination of each item reveals some interesting implications of the six models. There is unanimity across all the institutions regarding the impact that experiential learning has on informal student contact with 41 of the 44 respondents indicating that informal contact was either "much more" or at least "a little more" in the experiential curriculum.

FIGURE 9.3
PROGRAM INVENTORY
Demands of Experiential Programs Compared
To Traditional Curricula
All Institution Averages



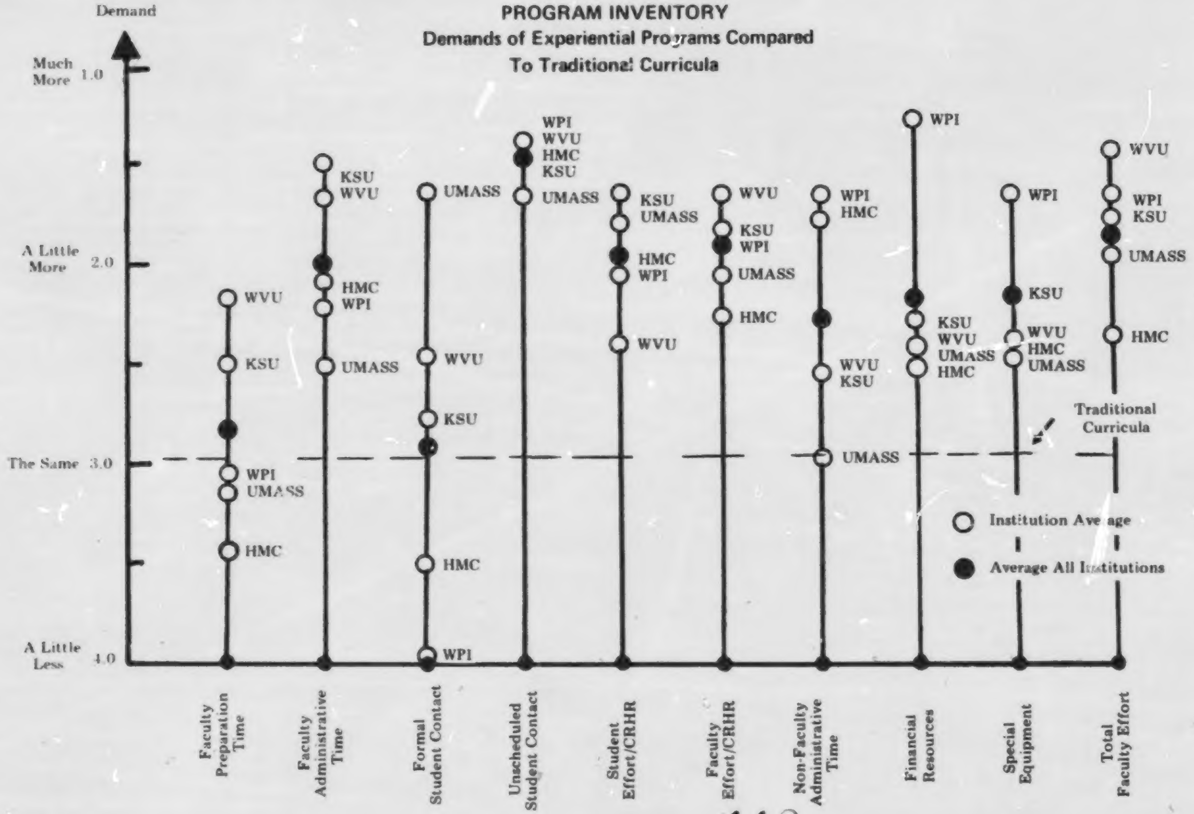
Faculty preparation time presents an interesting variety of opinion both across and within programs. At WVU, respondents were strong in their feeling that Guided Design required more preparation time. This is not surprising given that the faculty members are responsible for generating problems as well as authoring self-instructional texts on fundamental topics.

Within each school there is also a wide dispersion of opinion regarding the change in preparation time. For example, at WPI three faculty members indicated that experiential learning requires more time, whereas four faculty feel that it does not. At KSU, there is a similar dispersion with those faculty members not being directly involved in teaching the Design Lab saying that it requires less time. At the other institutions, there exists a similar pattern of disagreement. There is no straightforward explanation of this variance. Individual faculty experiences differ according to the type of projects their students encounter. These differences may reflect individual work styles, the amount of experience with the program, and the diversity in which people approach their work responsibilities rather than anything inherent in the programs.

Administrative time required to organize and run these programs is greater across all institutions. Faculty administrative time goes up significantly because faculty members must solicit projects, oversee student work, and act as quality control agents. Non-faculty administrative time, defined as organizational time and effort which is required of non-faculty professionals, varies according to the type of model. For example, at WPI, with over 800 projects a year, a special projects office had to be established. CINN's Co-op program extends across a number of colleges and is coordinated centrally through the Career Dynamics Center. All the other programs exist within academic departments and thus require no administrative time beyond that given by faculty members. These data show that as a program grows larger or extends across departments that additional administrative staff are required. Special offices must be set-up and persons with special skills must be recruited. Both the increase in faculty administrative time across all programs and the increase in non-faculty administrative time for large programs are important institutional implications which must not be overlooked.

These data reveal that each program results in a different mix of institutional implications. The UMASS model significantly increases both formal and informal student contact. The WPI program by virtue of its size requires increased administrative time and special equipment. CINN, with its total separation of on-the-job experience from the classroom, has little impact on the faculty role or the curricular structure. WVU requires a significant increase in faculty preparation time as a result of the use of simulated, faculty-designed projects. With HMC's use of graduate students to organize and lead team projects, faculty preparation time appears to be reduced in comparison to other programs; the comparative rating of faculty effort also is significantly lower than in other models. In summary, these data demonstrate that the type of model chosen translates directly into a different mix of institutional implications.

FIGURE 9.4
PROGRAM INVENTORY
Demands of Experiential Programs Compared To Traditional Curricula



The design of this study did not include a careful analysis of the incremental costs associated with experiential learning, yet the data which was selected does hint at some financial implications. As Table 9.1 indicates, these models are funded in different ways. Some have absorbed the costs as part of their institutional budgets. Others generate revenues by charging the client the total amount it costs to keep the program in operation. By their very nature these models also incur different types of costs. Institutional resources and special equipment required do seem to increase as a result of experiential systems, yet the faculty and administrative responses did not indicate that these costs are overwhelming. The greatest impact occurs in administrative time and faculty effort. Large programs require additional administrative help and perhaps the creation of a "projects" office. Although faculty effort may not usually be thought of as a financial item, it is short-sighted to think that this will not eventually translate into dollars. Faculty members cannot be expected to continually put forth this increased effort in conjunction with feeling the need for additional skills without eventually demanding some released time for personal development. Perhaps this is the greatest single cost of experiential learning both in human and financial terms.

Student Implications: Learning Outcomes and Satisfaction

The philosophies and the learning activities create differing outcomes. The learning outcomes of students, as perceived by faculty and students in each of the experiential programs are compared and then contrasted with self-reports on the traditional programs from the same respondents. These learning outcomes are also compared to the perceived importance of attaining this set of skills. From this analysis emerges the strengths and the weaknesses as well as the complementarity of the traditional and experiential components of an engineering curriculum.

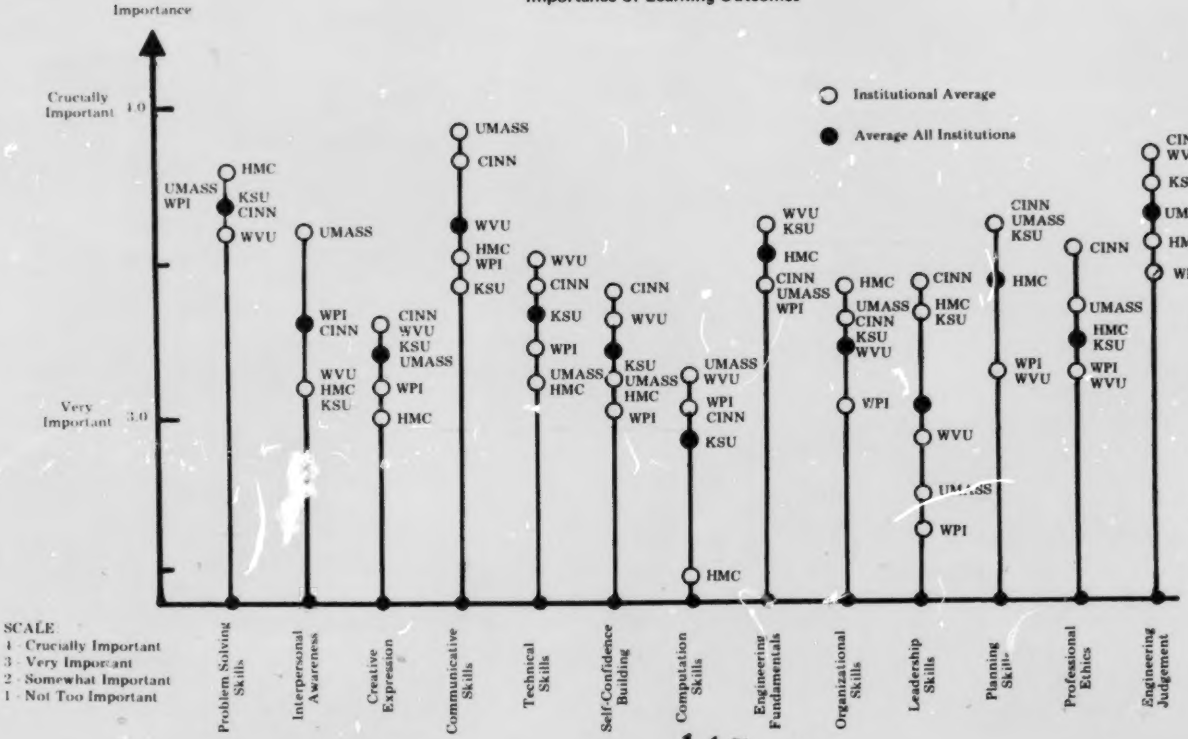
The Importance of Skills

To focus the goals of each program, respondents were asked to scale the importance to a set of thirteen possible student learning outcomes. These data comparing all six institutions are presented in Figure 9.5.

As the average of all programs demonstrates, each skill is regarded as at least "very important" with only Computational Skills falling slightly below a 3.0 average. Problem-Solving, Engineering Judgment, Communication Skills, and Engineering Fundamentals are assigned the highest all-institution averages, while Computational Skills and Leadership Skills received the lowest averages.

What is striking about these data is their consistency across all programs. For example, Problem-Solving Skills and Engineering Judgment are two of the three most important skills in each of the institutions. Even for the least

FIGURE 9.5
Importance of Learning Outcomes



important skills the same pattern holds with Computation Skills being one of the two least important in every program. This pattern is repeated for all skills, particularly the fundamental engineering skills, yet the exceptions point to interesting programmatic differences.

Note the extremely high ratings in the UMASS program for Communication Skills and Interpersonal Awareness. Contrast this with the ratings for the KSU program on the same two skills. The difference reveals the dissimilar goals of each program. The KSU Mechanical Engineering Department offers a strong, traditional curriculum for all of its graduates while the UMASS-ESIC program offers a non-traditional alternative within the Mechanical Engineering Department. The UMASS alternative strongly emphasizes the skills of Communication and Interpersonal Awareness and the importance ratings reflect these program objectives.

Another interesting departure from this pattern of inter-institutional consistency appears for Leadership Skills. UMASS, WPI, and WVU rank this skill as least important of all those listed whereas the respondents at CINN, HMC, and KSU place it in the "mid-range" of importance. This difference may be attributable to the format of the experiential component. UMASS has individuals rather than teams working on projects; WPI only encourages the team approach; and WVU, although requiring teams, does not emphasize the leadership aspects. At HMC the project leader is a well-defined and important role usually but not always held by a masters candidate.

In summary, the classical fundamentals of engineering education such as Problem-Solving, Engineering Judgment, and Engineering Fundamentals are regarded in each program as being very important student learning outcomes. The less traditional skills such as Communication, Planning, and Interpersonal Awareness are also consistently assigned high levels of importance. With only a few execptions there is little difference across institutions.

The Experiential Curriculum

Given the pattern of consistency and high levels of importance attached to each skill, Table 9.6 and Figure 9.6 examines the developmental opportunity and the perceived quality of this set of skills for the experiential component in each of the six programs. The left-hand portion of the table indicates how many respondents did and did not feel that the opportunity to develop a particular skill existed in the experiential program. The remainder of the table presents a program breakdown of the average quality ratings for the opportunity to develop each skill. Figure 9.6 is a graphical display of the data in Table 9.6.

When asked whether the opportunity to develop these skills in fact existed, for all skills the response was an overwhelming "Yes." In other words, the participants in these programs almost unanimously felt that the opportunity to develop each one of these skills was provided by the experiential program. The

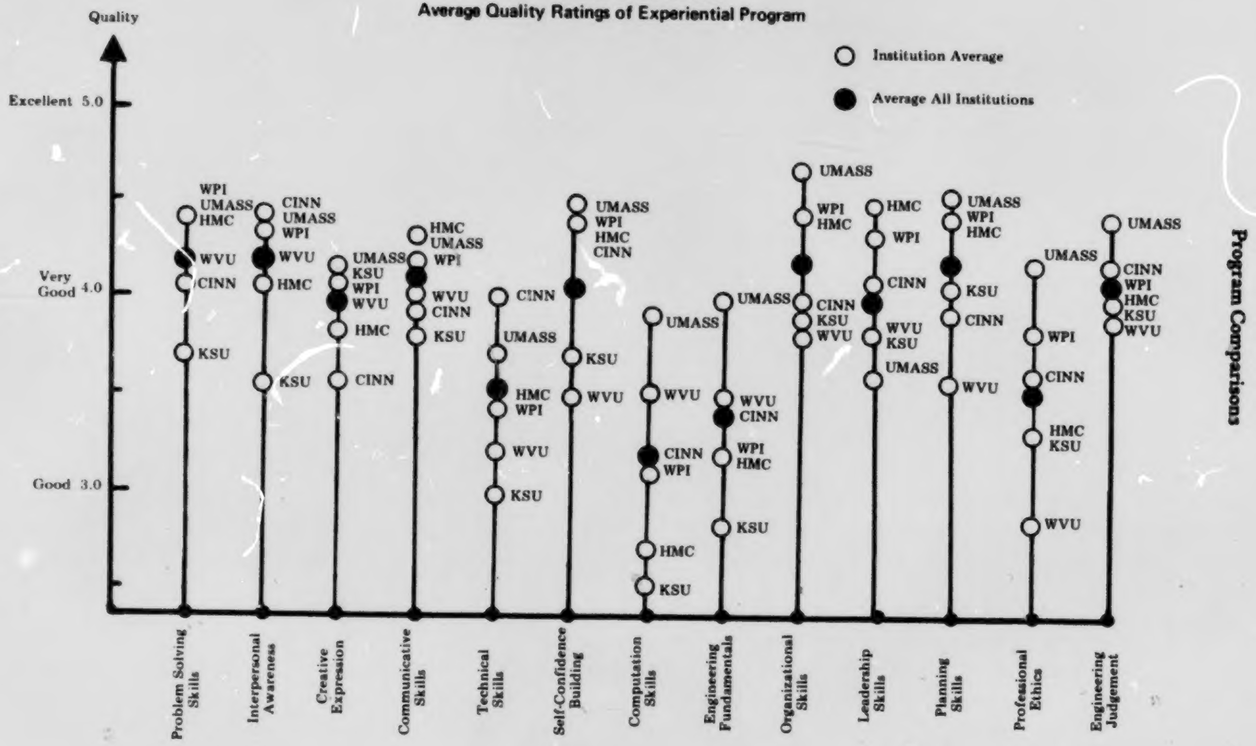
"No" votes for Professional Ethics and Computational Skills reveal some interesting program differences. For Professional Ethics--UMASS, WPI, and CINN had a nearly unanimous response that the opportunity did exist to develop this skill. The societal emphasis of the WPI program as demonstrated by the interactive qualifying project (IQP) affords students an opportunity to consider their own professional ethics. At UMASS and CINN both the emphasis on societal consciousness and the real world involvement with clients presents students with ethical choices at a time when they are developing their own set of professional ethics. This can be contrasted with the program at KSU in which students complete projects late in their academic careers and, in most cases, have presumably had an opportunity to develop a set of professional ethics.

For Computational Skills, HMC and KSU received most of the "No" responses. Because these experiential programs were designed to require a student to use existing technical skills rather than develop new ones, this response is not surprising. The opportunities which are provided students reflect the purposes and placement of the experiential component. The quality ratings of the experiential program accentuate this assertion as shown in Figure 9.6.

Overall, the institutional averages of the quality ratings for the experiential program, in Figure 9.6, reflect a high quality experience for many skills. Nine of the 13 skills listed in the inventory have an all-program average which exceeds 4.0 on the five-point scale. None of the skills receive a quality rating which dips below "good" (3.0) with the lowest ratings occurring for Computational Skills and Engineering Fundamentals. An examination of institutional averages shows that for the higher quality opportunities the ratings are very consistent yet for the lower quality opportunities there is more variation. This difference is related to the varying purposes of the experiential programs and should not be construed as a need for concern. For example, it is intended that Computational Skills will be acquired at UMASS through the experiential program whereas at KSU they will not be.

A program-by-program comparison of the quality ratings highlights the strengths of each of the experiential programs. At UMASS, students indicate that their highest quality experiences occur in developing Organizational Skills, Planning Skills, and Self-Confidence. At WPI, where the program thrust is similar to UMASS, students indicate that they have high quality experiences for the same skills but assign a relatively higher quality to Problem-Solving skills. At HMC, Leadership emerges as the highest quality experience, thus reflecting the team format of the projects. On-the-job experience at CINN promotes the highest quality ratings for developing Self-Confidence and Interpersonal Awareness. WVU with its heavy emphasis on problems and team generated solutions results in the highest quality ratings for Problem-Solving and Interpersonal Awareness. At KSU, the senior Design Lab results in the highest

FIGURE 9.6
LEARNING INVENTORY
Average Quality Ratings of Experiential Program



quality experiences for Planning Skills, Creative Expression and Engineering Judgment.

Overall the UMASS program has very high ratings across all skills and in general is characterized by higher ratings than the other experiential programs. Undoubtedly, the newness and small size of the program have resulted in an enthusiasm which is reflected in these ratings. Yet, these figures also reflect the careful design, high quality leadership, and thorough assessment procedures of this alternative within the mechanical engineering curriculum.

There is little doubt that these quality ratings distinguish among the different types of programs which have been established. Perhaps this is not a surprising finding. Yet, it reinforces the notion that different types of pedagogy do result in different perceived outcomes. In other words, the format of these innovations does matter. What remains is to validate in absolute terms that the students do gain these outcomes in the mix which is suggested here.

These findings also leave little doubt that various forms of experiential learning can result in high quality experiences for developing the requisite skills of practicing engineers such as Problem-Solving Skills, Organizational Skills, Planning Skills, and Interpersonal Awareness. Thus, if institutions perceive a need to strengthen their curriculum in these areas, experiential learning presents a viable alternative.

Finally, these data highlight the differing strengths of these six models. The UMASS model is all encompassing and occupies nearly all of a student's academic career from sophomore through senior years. Its purposes are different, the format is different and thus the qualities are different from the other models. In contrast, the CINN program also is placed throughout the undergraduate years but it is alternated with a traditional academic program. KSU is a two-credit, final semester design course. Each of these programs is strong in its intended areas, yet each is different in quality outcomes.

The Traditional Curriculum

To contrast the experiential program with the non-experiential program or "traditional" curriculum, program participants evaluated the quality of the opportunities in the traditional program just as they did for the experiential program. This data is presented in Table 9.7 and Figure 9.7. There is no intent to imply that these programs exist in opposition to each other. On the contrary, many of the experiential models were established to complement and reinforce the traditional curricula. The analysis in this section reveals that the traditional programs are very successful in accomplishing what they were designed to do.

As Table 9.7 indicates respondents are nearly unanimous in agreeing that the traditional curriculum provides an opportunity to develop the engineering basics of Computation Skills, Technical Skills, Engineering Fundamentals, and Problem-Solving. For the remainder of the skills, the responses are very mixed,

TABLE 9.6

LEARNING INVENTORY — ALL INSTITUTIONS

Average Quality Ratings For Experiential Programs

	Existence of Developmental Opportunity								
	Yes	No	All Progs*	UMASS	WPI	HMC	CINN	WVU	KSU
Problem-solving skills	118	2	4.2	4.4	4.4	4.4	4.1	4.2	3.7
Interpersonal awareness	117	2	4.2	4.4	4.3	4.1	4.3	4.2	3.6
Creative expression	112	7	4.0	4.2	4.0	3.8	3.6	4.0	4.1
Communication skills	119	0	4.1	4.3	4.2	4.3	3.9	4.0	3.8
Technical skills	116	4	3.5	3.7	3.4	3.5	4.0	3.2	2.9
Self-confidence building	115	4	4.1	4.5	4.4	4.2	4.4	3.5	3.7
Computation skills	105	13	3.2	3.9	3.1	2.7	3.2	3.5	2.5
Engineering fundamentals	102	17	3.4	4.0	3.2	3.2	3.4	3.5	2.8
Organizational skills	119	1	4.2	4.7	4.4	4.4	4.0	3.8	3.9
Leadership skills	111	8	4.0	3.6	4.3	4.5	4.1	3.8	3.8
Planning skills	116	0	4.2	4.6	4.4	4.4	3.9	3.6	4.1
Professional ethics	100	18	3.5	4.2	3.8	3.3	3.6	2.8	3.3
Engineering judgment	120	1	4.1	4.4	4.1	4.1	4.2	3.9	4.0

Program Comparison

Quality Scale: Excellent = 5; Very good = 4; Good = 3; Fair = 2; Poor = 1.

*This average was computed by taking a mean of the program means. Thus all programs are weighted equally.

with a significant percentage of students perceiving that the opportunity does not exist. For example, 49 of 115 (43%) respondents do not perceive an opportunity to develop Professional Ethics in the traditional curriculum; 49 of 117 (42%) responses are negative for Interpersonal Awareness; and 60 of 117 (51%) responses are negative for Leadership Skills. Although these percentages stand in direct opposition to the small percentage received for experiential learning, traditional programs rarely purport to teach many of these skills.

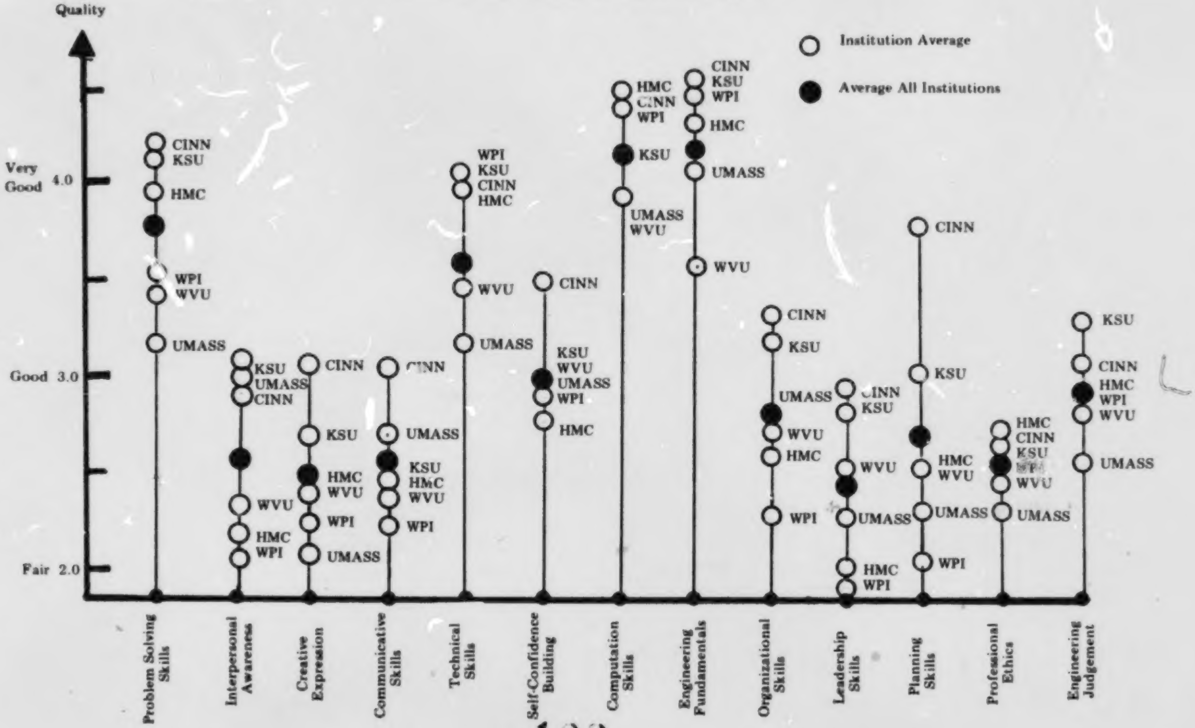
An examination of the quality ratings for the traditional program reveals some interesting patterns. The wide range of quality ratings for single institutions demonstrates that respondents distinguish between extremely high quality experiences for some skills and rather low quality for others. Closer analysis shows that there is unanimous agreement across all programs on the four highest quality experiences in the traditional program: Engineering Fundamentals, Computation Skills, Problem-Solving, and Technical Skills. Respondents are consistent and strong in their endorsement for the quality which the traditional program provides in learning these skills. For the lowest quality experiences there is some agreement, although the unanimous pattern is not evident. For example, Leadership Skills, Professional Ethics, and Interpersonal Awareness are regarded as the lowest or second lowest quality ratings (2.5) in at least four of the traditional programs.

In summary, there is unanimous agreement that the traditional program at each of these institutions is very strong in teaching the fundamental engineering skills. Although there are individual programmatic differences, the traditional program does not provide high quality experiences for the development of Leadership Skills, Communication Skills, and Creative Expression.

To further understand experiential learning as it relates to traditional programs, a direct comparison of the quality ratings within institutions is presented in Table 9.8 and in Figure 9.8. The statistics in the table are the institutional differences between the average quality rating for the experiential program and the traditional program. As the data demonstrate, there is unanimous agreement that the quality of the opportunity to develop Engineering Fundamentals is significantly greater in these traditional programs than in the experiential models (as indicated by the negative differences). Respondents also report higher quality experiences in the traditional program for the development of Technical Skills and Computational Skills.

In contrast, the greatest positive differences in Table 9.8 indicate the highest quality difference in favor of the experiential programs. For nine of the 13 skills listed, there is unanimous agreement that the experiential program provides a higher quality experience. Figure 9.8 shows that the greatest differences occur

FIGURE 9.7
LEARNING INVENTORY
Average Quality Ratings of Traditional Program



for Leadership Skills, Interpersonal Awareness, Planning Skills, Communication Skills, and Creative Expression. Again, it is important to remember that traditional programs were not necessarily designed to teach all the skills listed here, and that this inventory was designed to identify the skills associated with experiential learning.

To put this comparison in perspective, this information can now be contrasted with Figure 9.5 which rates the importance of students possessing each of these skills. Recall that nearly all skills were rated as important with Problem-Solving, Engineering Judgment, and Engineering Fundamentals regarded as the most important. The quality ratings show that Problem-Solving receives very high and comparable marks in both traditional and experiential components. Engineering Judgment receives a higher quality rating in the experiential programs across all institutions; whereas Engineering Fundamentals, also rated as crucially important, are best taught in the traditional program. Thus, the complementarity of experiential and traditional programs emerges as an important finding.

Although these data compare assigned degrees of importance to perceived learning outcomes, these findings must not be misinterpreted. These data do not contain information on the degree of effort it requires either to teach or acquire these skills. Similarly the time associated with learning a skill or acquiring a behavior is not discussed. Thus, although experiential programs do teach more of these skills with higher quality, important outcomes such as Engineering Fundamentals, Technical Skills, Problem-Solving may require much more course time to develop than other skills. These data do not support the conclusion that heavily experientially oriented programs are best, nor do they necessarily refute it. The data strongly support the contention that experiential programs do allow students to develop certain skills that are important and offer them a higher quality opportunity than do the traditional programs.

Attitudes Toward the Profession

Experiential education impacts on more than the development of professional skills and knowledge. Students attitudes are affected; and these attitudes, in turn, shape the direction and enthusiasm with which students apply their talents. In broad terms this study assesses how experiential programs contribute to students' attitudes toward their profession.

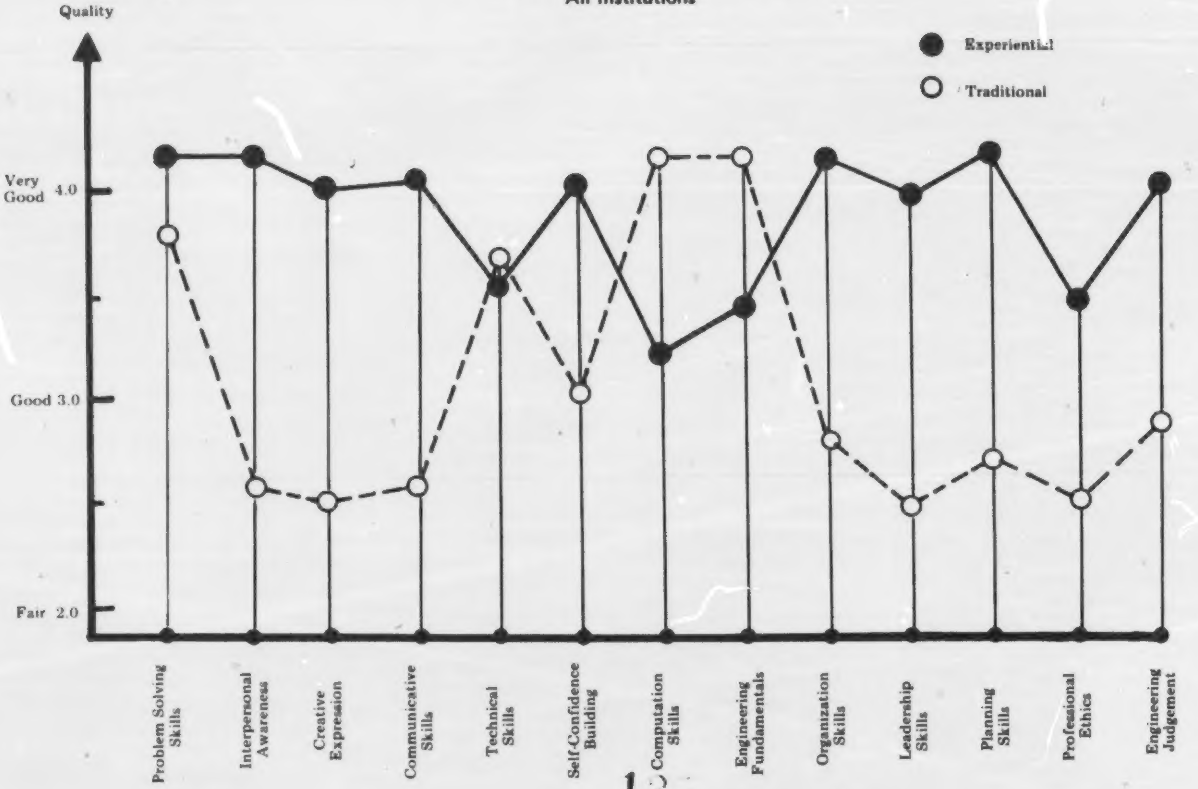
In this context, students were asked three related questions: 1) Do you feel you have a more realistic impression of engineering and engineers because of your involvement in the (experiential) program? 2) Are your impressions of engineering and engineers more positive, more negative or about the same as before your entry into this program? 3) How has the experience component affected your commitment to an engineering career? The responses to these

TABLE 9.7
LEARNING INVENTORY -- ALL INSTITUTIONS
Average Quality Ratings For Traditional Program

	Existence of Developmental Opportunity								
	Yes	No	All Progs*	UMASS	WPI	HMC	CINN	WVU	KSU
Problem-solving skills	113	6	3.8	3.2	3.6	4.0	4.2	3.4	4.2
Interpersonal awareness	68	49	2.6	3.0	2.1	2.2	2.9	2.3	3.1
Creative expression	83	34	2.5	2.1	2.2	2.4	3.1	2.4	2.7
Communication skills	90	28	2.6	2.7	2.3	2.5	3.1	2.4	2.5
Technical skills	114	6	3.8	3.2	4.1	4.0	4.1	3.5	4.1
Self-confidence building	95	23	3.0	2.9	2.9	2.8	3.5	2.9	3.0
Computation skills	118	0	4.2	3.9	4.4	4.5	4.4	3.9	4.2
Engineering fundamentals	114	4	4.2	4.1	4.4	4.3	4.6	3.6	4.4
Organizational skills	82	36	2.8	2.8	2.3	2.6	3.3	2.7	3.2
Leadership skills	57	60	2.4	2.3	1.9	2.0	2.9	2.5	2.8
Planning skills	88	28	2.7	2.3	2.1	2.5	3.8	2.5	3.0
Professional ethics	66	49	2.5	2.3	2.5	2.7	2.7	2.4	2.6
Engineering judgment	102	16	2.9	2.6	2.9	2.9	3.1	2.8	3.3

Quality Scale: Excellent = 5; Very good = 4; Good = 3; Fair = 2; Poor = 1.

FIGURE 9.8
Comparison of Average Quality Ratings
Experiential vs Tradition Programs
All Institutions



questions are presented in Tables 9.9, 9.10 and 9.11:

From these data it is clear that experiential education has an impact. On each of the questions, responses indicate that the "real world" affected their attitudes. Taken together these responses suggest that experiential learning promotes realism, that positive impressions are generated and that career commitment is enhanced.

This is not the case for all students, nor is it the case at each school. The negative responses suggest that experiential education may be a powerful tool in helping students sort out values and abilities and determine the "fit" between values, abilities and careers. Obviously, for some students the "real world" influenced their thinking toward career commitment. For others, commitment was already there and as a result, the program had little impact. Students seem least affected at KSU. This capstone program comes late in a student's development and is not necessarily intended to impact on these particular attitudes. However, it does promote realism and does have an impact on some of the program participants.

Student Satisfaction

This study probed student satisfaction to determine how satisfying experiential education was and to diagnose the strengths and weaknesses of an experiential system. Data were collected on five areas of student satisfaction; four focused on experiential learning and one on traditional learning. For experiential learning, students were asked to scale their satisfaction with the assessment process, their relationship with supervising professors, their relationship with clients, and their overall feeling about the experiential component of their program. Similarly, they were asked to scale their overall satisfaction with the traditional program. Figure 9.12 presents satisfaction information for all the students interviewed, and Figure 9.13 analyzes this information by program.

Figure 9.12 indicate that students are highly satisfied with their experiential learning endeavors. With the exception of those at KSU (Figure 9.13), these students are also more satisfied with experiential education than with traditional education. The limited scope of the KSU program may explain this reversal. High satisfaction with the new professor/student relationship is consistent across all programs. In contrast, satisfaction with client/student relationships and with the assessment process is quite variable. For several of the programs there appear to be weaknesses in these areas.

Figure 9.14 presents program satisfaction profiles. Satisfaction with the traditional and experiential components is most congruent at KSU and HMC. At the other four institutions, students are clearly more satisfied with experiential education. No program appears to have all the answers. Some programs are quite strong in some areas, while others appear a bit weaker.

TABLE 9.8

A COMPARISON OF THE QUALITY OF OPPORTUNITIES IN THE EXPERIENTIAL AND TRADITIONAL PROGRAMS

Difference Statistic = Experiential = Traditional

	ALL PROGS*	UMASS	WPI	HMC	CINN	WVU	KSU
Problem-solving skills	0.4	1.2	0.8	0.4	- 0.1	0.8	- 0.5
Interpersonal awareness	1.6	1.4	2.2	1.9	1.4	1.9	0.5
Creative expression	1.5	2.1	1.8	1.4	0.5	1.6	1.4
Communication skills	1.5	1.6	1.9	1.8	0.8	1.6	1.3
Technical skills	- 0.4	0.5	- 0.7	- 0.5	- 0.1	- 0.3	- 1.2
Self-confidence building	1.1	1.6	1.5	1.4	0.9	0.6	0.7
Computation skills	- 1.1	0.0	- 1.3	- 1.8	- 1.2	- 0.4	- 1.7
Engineering fundamentals	- 0.9	- 0.1	- 1.2	- 1.1	- 1.2	- 0.1	- 1.6
Organizational skills	1.4	1.9	2.1	1.8	0.7	1.1	0.7
Leadership skills	1.6	1.3	2.4	2.5	1.2	1.3	1.0
Planning skills	1.5	2.3	2.3	1.9	0.1	1.1	1.1
Professional ethics	1.0	1.9	1.3	0.6	0.9	0.4	0.7
Engineering judgment	1.2	1.8	1.2	1.2	1.1	1.1	0.7

Quality Scale: Excellent = 5; Very good = 4; Good = 3; Fair = 2; Poor = 1

*This average was computed by taking a mean of the program means. Thus all programs are weighted equally.

TABLE 9-9
Impressions of Engineering/Engineers

		MASS	WPI	HMC	CIN	WVA	KSU
more realistic impression	Yes	10	10	13	12	11	10
	No	0	0	0	0	1	4

TABLE 9-10
Change in Impressions of Engineering/Engineers

	MASS	WPI	HMC	CIN	WVA	KSU
more positive	8	3	8	8	7	2
more negative	0	3	1	0	0	0
no change	0	2	3	2	4	13
don't know	2	2	1	2	1	0

TABLE 9-11
Impact on Career Commitment

	MASS	WPI	HMC	CIN	WVA	KSU
more committed	7	4	6	5	7	3
less committed	1	1	1	0	1	0
no impact	0	2	5	1	4	12
don't know/other	2	2	1	1	1	0

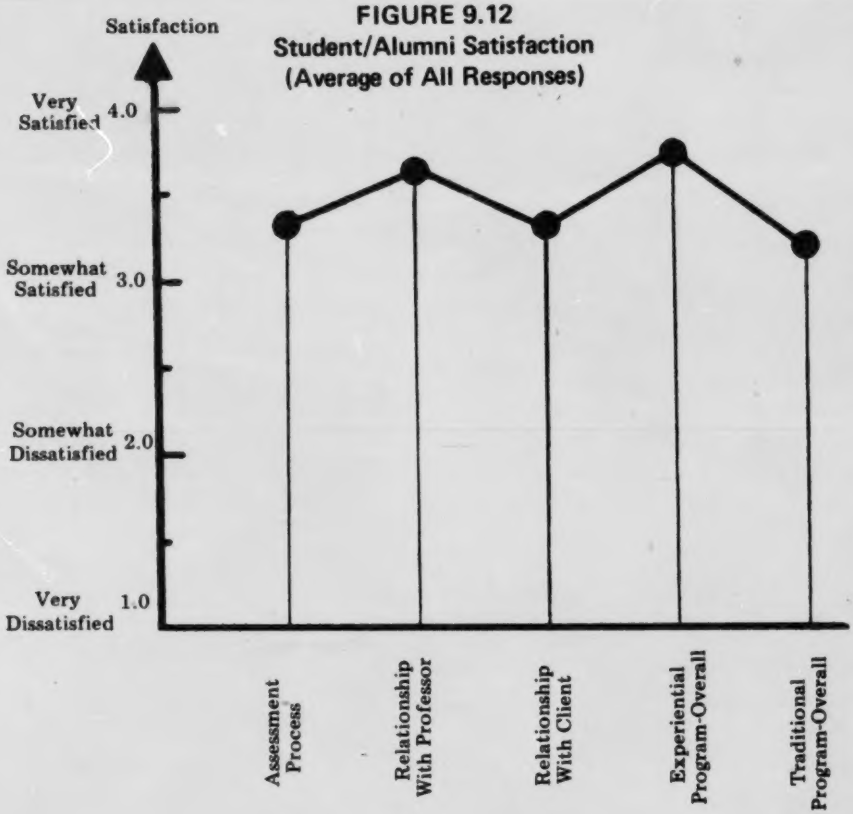
These data do, however, support the contention that students find experiential learning a highly satisfying experience.

Strengths and Weaknesses

It is difficult to succinctly summarize the diversity of these six experiential programs. Yet, some general strengths and weaknesses emerge from the interviews of program participants. There is little doubt that experience-based education creates a powerful learning environment which results in new educational outcomes. Yet, in each program, weaknesses appear that dilute the full impact of this new learning system.

The most consistently mentioned strength of experiential learning is its educational impact on students. New qualities are cultivated and new skills are

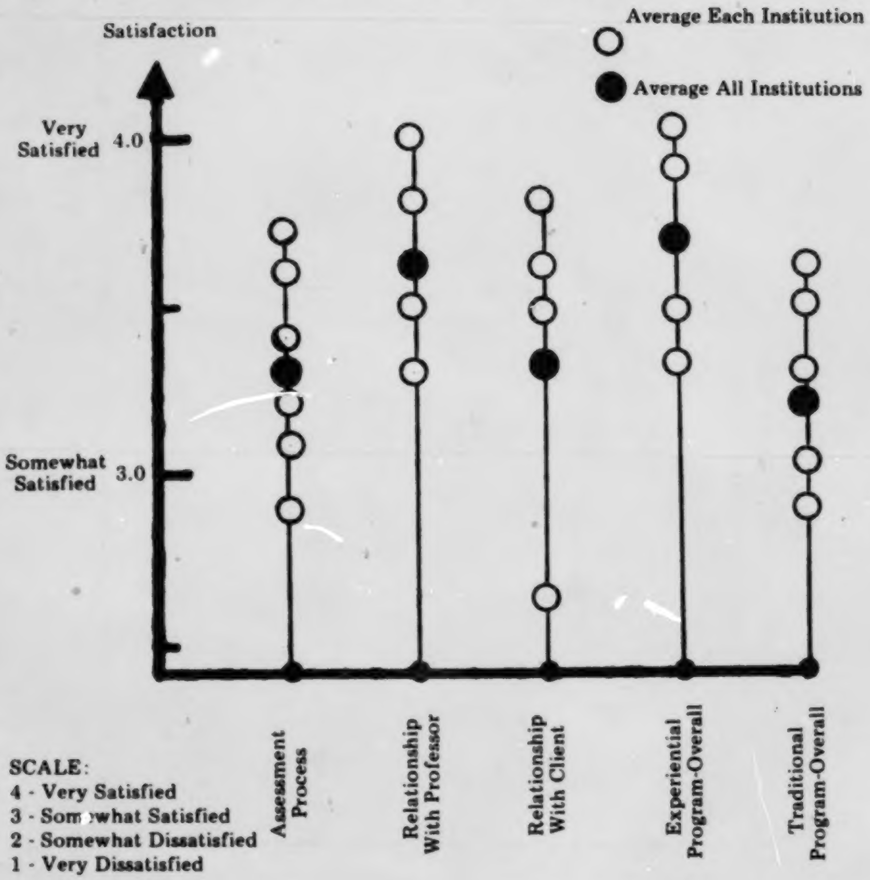
FIGURE 9.12
Student/Alumni Satisfaction
(Average of All Responses)



developed. Skills and attitudes which are important to practicing engineers, such as communication, planning, interpersonal awareness and organization, are developed through participation in these experiential programs. Problem-Solving Skills and Engineering Judgment also result. The skills most highly developed through experiential learning complement the strengths of the traditional curriculum. Taken together, the traditional and the experiential curricula provide the student with qualities deemed important in professional engineering practice. The program participants believe that the original purposes for constructing a "real world" learning experience are being accomplished. Experiential learning in these six models does make a difference.

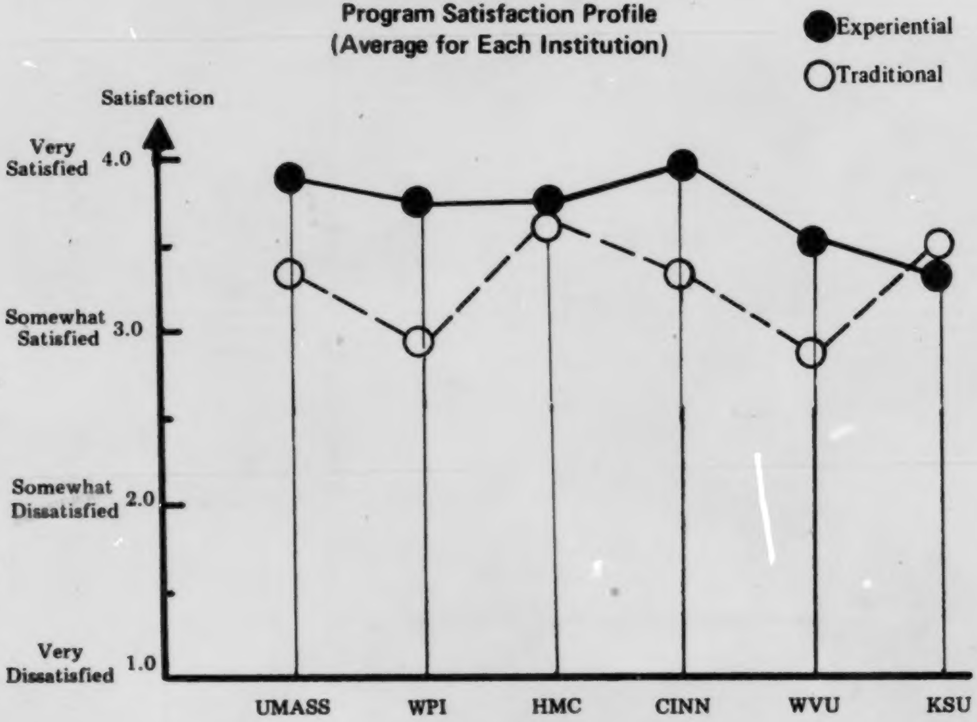
FIGURE 9.13

Student and Alumni Satisfactions



A weakness cited across all programs concerns "the project." This concern encompasses many different attributes of experiential learning from project selection to project diversity. For projects to realize their maximum educational potential, they must require an application of theory, must be open-ended and should not be characterized by a unique answer. Participants frequently cite the need for a diverse pool of project topics which, in turn, can satisfy the diverse interests of students and their far-ranging professional needs. In addition,

FIGURE 9.14
Program Satisfaction Profile
(Average for Each Institution)



varying substantive areas of engineering need to be solicited so that students can have a breadth of exposure. Comments were frequently made that reflected the difficulty in finding a good match between the student and the project. For example, "The project wasn't challenging enough," or "I just couldn't get a project that fit my exact interests." The importance of project selection defines what both the students and the faculty will gain from the activity.

The assessment process was another weakness pinpointed in several of the programs. New learning goals and a new learning environment may stretch traditional assessment procedures beyond their credibility. "How can interpersonal awareness, ethics, creative expression or self-confidence be measured?", "What criteria should be applied?" and "How will I know one when I see one?", are questions which exemplify the challenges faced by faculty members who are consciously breaking new ground. The assessment task is complicated by the team format in which the learning may be richer, but the assessment is far more difficult. Assessment in any educational system is inherently complicated; and as these faculty gain more experience, undoubtedly techniques and procedures will be improved.

Interestingly, none of the weaknesses cited by participants challenged the fundamental merits of the experiential approach. Rather, the weaknesses focused on refining and perfecting the existing programs. In general, program participants view the future from two perspectives. Those in the older established programs seek ways to refine their systems and retain vitality. Those in new programs seek ways of institutionalizing them into stable on-going segments of the total curriculum.

Experiential learning enhances a student's preparation for a practice-oriented engineering career. However, programs require sound conception, leadership, and management to fulfill their potential. Even if these requisites are met, as demonstrated by the programs in this study, experiential learning presents many pedagogical and management challenges.

10

Issues and Applications

We have described and compared six quite different approaches to experiential learning. It is evident that each of the programs is successful, not only in meeting the various learning objectives, but in providing a rich spectrum of experiences that are extremely satisfying and highly valued by both faculty and students. They all work!

Varied as the programs are, there is a remarkable similarity among the profiles of achieved learning outcomes. The differences in programs are reflected more in degrees of satisfaction of specific skills than in total omission or alternation of certain skills. The outcomes tend to vary more directly as a result of the variation of emphasis on particular goals and different activity mixes in the program. Each of the models provides opportunities to achieve a chosen inventory of learning outcomes at any level of success the faculty wishes to emphasize.

The study clearly shows that these six models develop a set of learning outcomes that are not generally achieved in traditional courses, such as communication skills. It also indicates there are learning skills that are better achieved by the traditional courses (Engineering Fundamentals). It seems logical to conclude that these experiential models promote a set of skills and attributes that are not as highly developed by a curriculum that includes only the traditional courses.

It is interesting to note that there is, in general, a high degree of student satisfaction and enthusiasm for the experiential learning activities. There also seems to be a relationship between level or degree or satisfaction and the amount of involvement in client projects. The two program models that required a continous and total involvement in engineering activities with industrial clients throughout most of the tenure of the degree programs received the highest satisfaction profiles. A modest involvement occurring at the end of the degree program seems to leave the least impact on satisfaction and commitment. Thus the degree of immersion in the "real thing" may be a strong factor in generating the self-satisfaction of involvement, accomplishment, and commitment.

The management of the experience is indeed a strong force in determining the quality of the outcomes for the student. The success of experiential learning, as would be expected, is supervision-dependent. In the Co-op program, the quality of experience is directly related to how conscientious and experienced the employer is in both shaping the work activities for the student and in feeding back performance evaluations. In the faculty supervised programs, the outcomes are heavily dependent on the supervisory style and guidance of the faculty. The "chief engineer" role of the faculty is one that is both demanding and satisfying. It is evident that the faculty "load" is no more than that required of a conventional laboratory, although the amount of time and effort varies with individual faculty work styles and student needs. In general, in all the models, the value of the outcomes for the students reflect directly on the close counsel and guidance received from those supervising the experience. A colleague relationship develops that is not only valued by both, but is a requisite for learning.

The cost of experiential learning programs is difficult to assess since most institutions do not keep direct cost records. There are indications that these programs demand more effort than conventional classroom instruction. However, the programs do not necessarily require the capital investment of a laboratory, if the activities are generally more analytical than experimental. The cost should be essentially related to faculty time required per credit-hour generated. Cost estimates are inconclusive. Some experienced faculty in the well established programs report the effort equivalent to conventional instruction. There is an administrative cost both in time and communication. However, direct costs for the student activities (phone calls, report preparation, travel, experimentation) can be and usually are charged to the client. The opportunity also exists for charging the client for some of the indirect costs as well (as at HMC). With the exception of the Co-op program (which usually requires additional professional staff), these programs seem to cost out between the conventional course and a laboratory. But, with good management and the availability of direct project funding they realistically can become even more cost effective than classroom instruction.

Points To Ponder

An involvement in experiential learning brings about a confrontation with a number of issues. Each of the models studied here created a unique impact on all who were involved and raised a number of basic and important questions.

Some of these questions may have already been answered. Some may have to be answered by experimentation, rather than by logic. Some may never be resolved. An overview of all the models prompts a number of questions and some points worth pondering:

Issue #1 - Faculty Involvement

Is Experiential Learning important enough to require all faculty to be involved? How much?

How should faculty be recognized and rewarded for supervision of this type of learning activity?

Should a specific training and diagnostic evaluation procedure be developed to assist the faculty in optimizing their performance in this new role?

What is the most effective faculty role? Manager? Counselor? Consultant? Evaluator? Tutor? Chief Engineer?

Can involvement in experiential Learning Activities be a supplement to or an alternative for research and consulting in the professional development of the faculty?

Issue #2 - Curriculum

Where is the balance between the development of fundamental skills and the development of practice skills?

Something has to give--which courses and learning activities are to be dropped in order to add the experience activities?

In the total involvement programs (such as WPI and UMASS) can the students develop an adequate basic background?

How much time should be allotted to experience based activities?

Does project activity trend toward narrowing of experiences and specialization at the expense of generalization?

Where should the experience component be placed in the curricula?

Is a capstone experience too late to be effective?

Issue #3 - Learning Objectives

Which attributes and operational skills should be emphasized to capitalize on the resources of the institution and the opportunities of project activity?

How important is an emphasis on developing a strong career commitment to engineering and professionalism?

Which skills are better learned in a simulated environment, which in a "real world" activity, and which "on the job"?

How much diversity should there be in project activity?

What is there in "real world" experience that needs to be learned that defines the "real world"?

What activity creates or enhances "learning how to learn"?

How much weight should be given to project planning (PERTing), written and visual presentations, library research, laboratory experimentation, computer use, leadership, and ingenuity within project activity?

Issue #4 - Client-Institution Interface

How can academic and scholarly credibility be protected and maintained in concert with the practice emphasis in experience based projects? What is a compatible mix? What establishes an acceptable project experience? Or, an acceptable "real" project?

How much responsibility can there be assigned to the client in creating a meaningful experience for the student?

How formalized must the relationship between client and institution be to accomodate the issues of safety, liability, ownership of inventions, and the desired academic and project outcomes?

Issue #5 - Evaluation

Should the evaluation process provide a standard letter grade or should these activities be assessed with merely a pass-fail or an S-U recorded for the record?

Who should be involved in and contribute to the performance assessment?

Must the assessment of experiential activities be totally behavior oriented and subjectively derived or should there be some objective measures included?

How much structure should there be to the entire process of critique and assessment while the students are involved in the activities?

Issue #6 - Institutional Implications

How much institutional commitment is needed for a successful program?

What is the institutional responsibility regarding the learning outcomes achievable by experiential learning? How much should be shoved off on to the first employer?

How do you convince faculty to accept and make a commitment to develop an experience based program?

Is experiential learning to be an alternative or a substitution or an adjunct to the degree program?

Where will the responsibility be placed to sustain the program and make it flourish?

These questions essentially define decision points in the process of planning and implementing an experiential learning program. Each of the "Issues" has to be addressed and the choice must be drawn from the experiences of the present working models or derived as a new experimental venture. Perhaps a critical issue and a serious point to ponder is:

Who is to take the initiative and provide the motivating force to meet the issues and develop the commitment?

Every new program must have a champion and a commitment of resources to support both the development and the operation. If the program is to be a small subset of the total program, (as at UMASS), few are involved and the institutional impact is minimized. If all faculty members are involved, as at WPI and HMC, great pains must be taken to win the support of a vast majority. In any case, there will be a cadre of the loyal opposition that must be accomodated as a part of the price for succeeding.

Making A Choice

Anyone interested in this study is ultimately going to reach a decision point about being involved in experiential learning activities. If the decision is to get involved, then there follows the difficult task of choosing the format. The choices are many. There is no ''first'' choice among the models examined in this study. It was demonstrated that each is capable of accomplishing any chosen set of experiential objectives. The study also reveals the impact of the various activities within the programs on the outcomes. Thus, there is an opportunity to custom make a model from ''pieces and parts.''

What is done depends on the priorities given to the many program alternatives. The priorities will be influenced in part by the existing campus organization, the locale, and the personalities and preferences of the faculty. But, the controlling factor will be the selection of the learning outcomes that are to be achieved. The listing in this study of the ratings of importance and satisfactions within the learning inventory for each of the models will be helpful.

What about a composite model? Is there a combination of procedures that can be derived using the best of each? Probably, if there could be agreement on what is best. The attempt here to construct a composite model reflects personal biases, but is derived from the experience of investigating various successful programs and reflecting on this information.

The following suggestions may be helpful in considering the alternatives:

1. Amount of Involvement--At least one academic year should be the minimum to provide an opportunity for growth within the experience. The practice of beginning the experience component after two or more terms of preparatory course background has merit. The rigor and responsibility within the experience should increase as the student progresses. The total involvement program of the USMASS-ESIC model could be a parallel option in any discipline for selected students regardless of the other experience

programs in use. A minimum of three credits in the degree program should be assigned to an experiential learning activity.

2. Internships or Consulting--The internship of the Co-op program is indeed a valuable experience and, for some students, a needed economic advantage. A Co-op program can easily be an option regardless of other programs. There are advantages to offering the Co-op student the added experience of project management and team activity through a faculty supervised consulting project in parallel or as a capstone to the internship. All Co-op students should, however, also be involved in a faculty supervised learning activity that provides closure on the intern experiences. The client-based project activity should be structured to provide a project experience with more than one client and an opportunity to work on both technical and socially oriented projects (such as the MQP-IQP at WPI). In any case, the student should have a project activity or internship with at least one off-campus client.

3. Client or Simulations--There is merit to having both client-based projects and instructor designed simulations. Early in the program a well structured activity using instructor designed projects, as in PRIDE and Guided Design, would provide an opportunity to develop specific experiences and skills before taking on client-based projects or internship. Maximum learning is facilitated by a combination of both types of experiences.

4. Project Selection--Projects should be selected to fulfill the spectrum of experiences that provide the desired learning outcomes, and to match the experience and maturity of the students. The activities should have enough alternatives so that a student can select or be assigned to an activity that matches his interests or needs. Ideally the student should be able to choose, as at WPI, between proposing a self-initiated project, a client or a faculty conceived project, a clinic experience at a Center, or an internship as in Co-op. The faculty should have the total responsibility for approving the selection of the projects or work experiences.

5. Team or Solo Experiences--The logistics of project management and interpersonal learnings usually encourage the use of teams. The benefits are many. At least one team project experience should be mandatory. Opportunities to develop team leadership

should be built into the program. Team size can vary to meet the situation but four seems to be an optimum number. Conversely, the ESIC program demonstrates the value of solo projects. The solo option should be available, and a mixture of the two considered.

6. Faculty Involvement--A team of the faculty in the discipline should have supervisiory responsibility for program. The involved faculty should agree on format, criteria, and procedures and work together to operate and improve the program. The faculty should be rotated on and off the team on an assigned tenure scheme to increase faculty involvement, assure continuity, and provide variety. One faculty member should serve as coordinator for the program. An average number of students for a three credit-hour course load equivalent should be about 16 students per faculty member. (Four teams). There must be recognition of the faculty role in experiential learning activities in the assessment promotion, tenure, and professional development.

7. Critique and Evaluation--One of the basic needs in an experiential learning program is closure. The supervising faculty must establish a clearly defined procedure for monitoring progress and evaluating achievement. Each faculty member should schedule periodic conferences with each project team. There should be a schedule of group meetings wherein each project team is to present a progress report to all participants. These live presentations should be made public for all faculty and students to attend, as at HMC. A panel of faculty, students, and consultants should be chosen to critique the presentation. Written progress reports as well as a written and oral final report to the client should be mandatory. The ESIC requirement that each student maintain a project log should be considered. The clients should be asked to submit a written critique of the reports and results of the study. Performance evaluation questionaires should be developed. Each student should submit a self assessment and an evaluation of each team mate. Clients and faculty supervisors who have had an opportunity to observe the teams at work should also submit performance evaluation forms. A final grade should be awarded for the activity based on a well defined and publicized procedure for determining the grade. Facilities and opportunities for improvement--such as writing clinics, leadership labs, or speech workshops--must be provided in order to fully complement the evaluation effort.

Future Trends

This study indicates that any trend in the development of new experiential learning activities will not be based on "if" they are implementable. It will be based on "whether" the decision makers think experiential learning is necessary. From the success profiles of these models one could speculate that it can and needs to be done for all students. The learning outcomes which these programs produce are the attributes most valued in the practicing professional. Today, there seems to be increasing emphasis on professionalism and a need to be able to address and solve complex, interdisciplinary, social-economic-technical problems. This indicates a need for experiential learning activities and a guided internship in the practice of the discipline.

Perhaps the controlling factor on the trend of the future may well be the problem of implementation. We all seem to know how to do twice as much as we actually do. Implementation of something new generally results when "should" becomes "have to" or "want to."

Developing a new program requires substantial effort and dedication on the part of all involved. All of which becomes justified when there is an institutional commitment that provides the necessary support and recognition. An aware faculty is a prime prerequisite for an institutional commitment. Hopefully, this study will contribute to an awareness of the value and opportunities in experiential learning programs.